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COST ANALYSIS FOR DUAL SOURCE WEAPON PROCUREMENT

by

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and

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It is widely held that competition can produce savings in the acquisition cost of weapon systems. However, a recent study of seven programs shows only three generated sufficient savings to offset the investments required to obtain them. Our study finds that the savings depends on how "hungry" producers are. When a loss has resulted, capacity utilization has been above 80%.

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PREFACE

The research effort represented by this report was funded under ONR grant No. N0001483WR30236, dated 28 December 1982. The Statement of Work which specified the task to be accomplished read as follows:

> Market environments relevant to the sole source versus dual source decision for the procurement of major weapon systems will be identified. The pricing behavior of contractors operating in these environments will be analyzed, and its potential impact on program cost will be studied. Suitable data from NAVAIR's contract file will be used, if appropriate, for empirical verification. The objective is to derive an optimal acquisition strategy for the various market environments.

Hopefully, the reader will judge the SOW to have been satisfied. In our own opinion it has been exceeded, due largely to the diligent assistance and efforts of an assemblage of knowledgeable and interested people. No study of this magnitude is undertaken without help, but the quality of the cooperation we received was exceptional. Among those making special contributions were Dan Nussbaum and Wayne Wesson, of the Naval Air Systems Command. Mike Beltramo and Dave Jordan, of SAI, also served their advisory roles above and beyond the call of duty. We are particularly indebted to LT David Britt, NPS graduate, who spent countless hours gathering and analysing data. Finally, James Smith, Director of the Navy Accounting and Finance Center's Planning Division, deserves special recognition for "bringing it all together" and "making it happen." The authors alone, of course, accept full responsibility for whatever shortcomings and errors the work may contain.

EXECUTIVE SUMMARY

With growing austerity pressures from the Administration, Congress, and the general public, DoD decision makers are under a mandate to use scarce resources wisely. It is a widely held belief that competition can produce great savings in acquisition costs. However, much careful analysis of the financial implications of competition shows that savings cannot be expected from every competitive procurement.

Regardless of whether a procurement is for a spare part, clothes, electronic components, or an advanced major weapon system, it is generally true that if the following two conditions are met, price competition is a possibility:

1. Adequate product description--The product is describable in a rigorous but not overly restrictive manner so potential suppliers can understand and comply with the Government's requirements.
2. Availability of suppliers--The Government has access to at least two independent suppliers with the technical competence, requisite facilities and willingness to satisfy the requirements.

The reprocurement of major weapon systems, however, may or may not be a good setting in which to implement competition. The decision requires in-depth analysis on an individual case basis. Unfortunately, DoD has no exact method for deciding when to introduce competition, or even whether competition should be introduced.

The most viable solution is to identify the major price determinants that would capture the essense of pricing behavoir for a group of major weapon system suppliers. The objectives of this study are therefore:

1. To identify the **significant** variable(s) that must be considered in evaluating the dual-sourcing strategy.
2. To estimate a reasonable range of values for major relevant variable(s) to facilitate estimation by practicing analysts.

In this study we have found that the most significant question to ask is,

> How do conditions of industry capacity utilization affect the competitive environment in the market, which itself is an essential element in sole-source versus dual-source decision?

Study Apporach and Organization

The study approach used in this project is mirrored in its organization. We begin with a thorough search of the relevant literature. Empirical works investigating potential savings from introducing competition as well as theoretical literature dealing with price competition are reviewed.

DoD contractor profitability is very much a related issue. Some feel defense business profits are too low. Others allege defense contractors earn "excessive" profits. We address the contradiction between these viewpoints.

Next we turn to the heart of the question--the dual sourcing of a selected group of major weapon systems. We combine the results with contractor and industry data which were extracted both from prior studies and from various other sources for analysis. Based on this analysis, many of the important variants of the sole source versus dual source question are addressed.

Finally, under the premise that actual payoff to the Government is available only through application, we explore the financial consequences of making the dual sourcing decision with the method we develop.

Literature Review

In Chapter 2 we review the findings of the important past studies of the effects of competition on DoD acquisitions. Past empirical works on the costs and benefits of introducing competition may be grouped broadly into two categories: those examining the effects of competition on a specific program, and those examining a selected sample of programs. Findings from both groups have shown both positive and negative results when weapon systems which were previously procured on a sole-source basis are dual sourced.

Empirical studies in recent years have documented cases where increases in production rate have been associated with increases, decreases, and no change in the unit production cost of weapon systems. The theoretical foundation of a production rate impact on cost is closely related to the theory of economies of scale. However, to address the issue of the impact of production rate on program cost, one must make a subtle distinction between the extent to which a firm is utilizing its overall production capacity and the rate at which the units procured under a particular program are being produced.

To introduce a second source for a major weapon system, additional investment over and above what would be necessary for a sole-source award is required. These include the cost of transferring a complex production technology, and of the additional costs which must be incurred to set up and manage a competitive production environment. It is difficult and expensive to get a good technical data package (TDP) for the second contractor, and even more difficult to persuade the first producer to pass along to a competitor the benefits of his manufacturing experience.

When a second source is to be introduced during the production phase, another important question is: "What will the first unit price be for the second source?" It is common for the second source to have a lower first unit price than the initial source did. Although the impact of the many relevant factors on the second source's first unit price

cannot be measured directly, surrogate measures have been attempted by several analysts.

The ability to estimate the the effects of competition on price reduction rates is essential in determining the amount of potential savings in recurring unit cost. It is generally expected that the unit price of products will drop under competitive pressure. The size of the expected savings may be a function of three factors:

1. a one-time, probably immediate, reduction in unit price when competition begins--the so-called "shift,"
2. a continuous, or sustained reduction in price because of a steeper price-reduction curve ("rotation"), and
3. a change in unit production costs because of the reduced production rate.

There are many studies that have addressed the issues of estimating the shift and rotation of price-reduction curves when competition is introduced, but the results have been far from conclusive. Attempts to identify explanatory factors have generally failed.

The decision to introduce a second source for a major weapon system requires a prospective evaluation of the financial consequences, but it also requires evaluation of a wide variety of other factors which, by nature, do not easily lend themselves to quantified analysis. The rich literature on competition covers a spectrum of factors and variables to be considered by the decision maker.

<u>Contractor Profitability</u>

Clearly, the price the Government must pay to acquire goods from a contractor serves two functions. One of these is to reimburse the contractor for the costs it must incur to supply the goods. The other is the generation of profit. Most past studies have failed to make this distinction and have

therefore failed to capture the volatility of the price the Government must pay under different market conditions.

In Chapter 3 we examine data covering 20 years, and study how the profitability of DoD contracts has been influenced. We ask how profitable contractors are in their DoD versus commercial business segments, and whether the risk levels faced are equivalent.

Our conclusion is that Program Managers (PM's) have been able to take advantage of the bargaining power they hold to buy goods at substantially lower profit margins when capacity utilization is low. The returns earned by contractors on DoD business are measurably lower than the returns on commercial business during periods of low capacity utilization.

Also, the volatility of returns is higher for DoD business which means the risks are viewed by management as being somewhat higher. In short, there appears to be reason for concern, given management's outlook on the risk/return relationship for DoD business.

Determinants of Price

"Rule of thumb" quantifications of the savings resulting from competition have been disappointingly unreliable. The research which has been done on the known histories suggests that dual sourcing of major weapon systems has resulted in added life cycle costs as often as it has produced savings

Most recent attempts to sharpen our cost estimation abilities have focused on adding a production rate term to the conventional learning curve model. However, the magnitude (and even the direction) of the effect on total program cost of altering production rates is not always foreseeable--particularly under dual sourcing. So its inclusion in the model, while often helpful, sometimes leads the analyst astray.

In Chapter 4 we learn that the effect of competition on the cost of acquiring major weapon systems under dual sourcing can more reliably be estimated by substituting an industry capacity utilization concept for the production rate concept. Simply said, competition produces greater savings

when firms are "hungry;" when the industry is very active, dual sourcing is of little benefit as a cost reducer.

As a demonstration, consider Table 0.1. The program savings (loss) data were taken from SAI's report [Beltramo and Jordan, 1982]. The capacity utilizations were averages of the annual figures for the aerospace industry for the years during which dual-source procurement was in effect for each program.

TABLE 0.1

A Simple Demonstration

Procurement Program	Percent Savings or (Loss) Due to Competition	Annual Average Capacity Utilization During Dual Source Phase
TOW	26.0	63.5
Rockeye Bomb	25.5	70.9
Bullpup AGM-12B	18.7	76.2
Shillelagh Missile	(4.7)	87.0
Sparrow AIM-7F	(25.0)	81.6
MK-46 Torpedo	(30.9)	91.6
Sidewinder AIM-9D/G	(71.3)	82.3

By examining Table 0.1, the reader can confirm that SAI determined that only three of the seven programs generated sufficient savings from competition to more than offset the investments required to obtain them. (In calculating these savings, Beltramo and Jordan followed the recommended procedure of applying a 10% discount rate to the estimated cost savings, and deducting the cost to the buyer of establishing competition.) In each of the three "savings" cases, industry capacity utilization averaged less than 80% during the dual source phase of the procurement. Each time a loss resulted from competition, capacity utilization was running above 80%.

Our interpretation is that greater savings do appear to have resulted from competition when capacity utilization was relatively low. Indeed, implementation of dual sourcing

when capacity utilization was higher than about 80% seems to have been, in retrospect, unwise.

Implementation

Based on the analysis contained in Chapter 4, we conclude that knowledge of the state of capacity utilization in the aerospace industry is an important component of the correct management of acquisition programs when competition is in effect. However, we find that more research is needed to enable us confidently to implement such concepts.

In this final chapter we discuss the possibility of implementation. Of specific interest will be our ability to make *ex ante* use of the "80% rule" as a practical, money-saving procurement tool. We feel it would be necessary to make improvements in our ability to forecast aerospace capacity utilization before it could actually be used as a decision variable.

Some with whom we have discussed the results of our work have pointed out that the model could be improved by using the capacity utilization measures for particualr firms rather than for the industry. We totally agree, and would like to explore this improvement. Our model, however, may be viewed and used as a "scoping" device to examine the most likely outcome under given market conditions. This important consideration has to date been ignored.

The results of the study point the way for development and implementation of superior acquisition strategies. The strategies which should follow will be applicable to various market environments.

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Chapter 1
INTRODUCTION

There are two reasons why the cost estimating methods used in defense acquisition are appropriate subjects for an in-depth, financial management improvement analysis. First, although the total proportion of the defense budget which goes for major weapon systems acquisition is smaller than the part devoted to personnel and other operating expenditures, the funding for the latter is somewhat automatic while the funding for the former must undergo closer scrutiny by both DoD and Congress during the annual budgeting process. In the early stages of the development of a new system, the cost depends on so many variables that the estimating process necessarily requires assumptions about future governmental decisions as well as on the market environment in which the procurements will take place. Substantiating the budget request requires "what if" drills to generate reliable cost figures.

Second, with growing austerity pressures from the Administration, Congress, and the general public, DoD decision makers are under a mandate to use scarce resources wisely. It is a widely-held belief that competition can produce great savings in acquisition costs. However, savings cannot be expected from every competitive procurement. A careful analysis of the financial implications of competition under different market environments is therefore essential to the efficient and effective utilization of public resources.

1.1 NEED FOR COMPETITION

There is a deep-seated and historic belief that the best model for Government procurement is solicitation of price offers from a maximum number of qualified sources. Indeed, there are many advantages to the Government of competition if it is applied properly. Various imperatives for competition in defense procurements will be discussed below.

1.1.1 Competition Imperatives

Since 1809, statutes, regulations and executive orders have consistently affirmed the position that government procurement must be made on a competitive basis to the greatest possible extent. In 1969, the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee called for vastly expanded use of competition for procuring all Defense Department material. This position was reaffirmed by the current Administration in the Carlucci Initiatives [1981].

> We are convinced that we have now a historic and unique opportunity to significantly improve the Defense acquisition system. We ask for your cooperation and assistance in carrying out these decisions.

1.1.1.1 Financial Benefits

In 1965, Secretary of Defense R. S. McNamara reported to the Joint Economic Committee that the General Accounting Office had evidence of dollar savings on the order of 25% or more when competition was introduced for reprocurement of an item which had a sole-source producement history. Since then, this 25% saving figure has been quoted repeatedly. While there are questions about the generalizability of the statement, the fact remains that, in a competitive market environment, the price paid by the buyer tends to move in the direction of the minimum costs of production.

1.1.1.2 Mobilization Base

In the interest of industrial mobilization, the DoD may introduce competition to strengthen the defense industrial base. The Defense Acquisition Regulations provide general authority to develop and implement plans and programs to provide an industrial mobilization base which can meet production requirements for essential military supplies and services, and specifically accommodates the division of production requirements between two or more contractors to provide for such a base.

1.1.1.3 Improved Technical Performance

Improved equipment performance frequently results from competition. A fresh look at the hardware by competent engineers of the competing firms often results in technical improvements and better problem solving techniques.

1.1.1.4 Social and Political Considerations

Although cost reduction, mobilization base and improved performance are important reasons for introducing competition, it may also be desirable for a wide variety of other purposes. At the legislative level, competing suppliers have been awarded contracts for the sake of fairness, evenhandedness, employment, or other political and social considerations.

1.2 REQUIREMENTS FOR COMPETITION

In spite of the overwhelming opinion favoring price competition, and formal commitment to its use, the DoD has historically employed this method for only about a third of its total procurement dollars. This is because the defense market is different from a traditional competitive market.

Competition in traditional markets arises when buyers and sellers are numerous and individually so unimportant in the market that their separate actions have no meaningful impact on market price. While some items in fact are procured by DoD in such a market, many important aspects of the DoD market for other items are different. DoD is often the only buyer, and consequently exerts complete control over market size, the timing of demand and, indeed, whether there will _be_ a market. Products usually do not already exist but, instead, are created at the behest of DoD.

Regardless of whether the procurement is for a spare part, clothes, electronic components, or an advanced major weapon system, it is generally true that if the following two conditions are met, price competition in the DoD market is financially desirable:

1. Adequate product description--The product is describable in a rigorous but not overly restrictive manner so potential suppliers can understand and comply with the Government's requirements.
2. Availability of suppliers--The Government has access to at least two independent suppliers with the technical competence, requisite facilities and willingness to satisfy the requirements.

Using these two requirements to evaluate the potential for competition, one can easily conclude, as confirmed by recent studies, that small value items with large quantity requirements, and products that are identical to or close derivatives of commercial products, are the best candidates for price competition--and that major weapon systems R&D and initial production may not be good candidates.

It may or may not be prudent to reprocure major weapon systems through competition. The decision requires in-depth analysis on an individual case basis due to the uniqueness of each system.

1.3 COMPETITION IN PROCUREMENT OF MAJOR WEAPON SYSTEMS

Procurement of major weapon systems poses a unique problem. Since the Government is the only buyer, it dictates the size of the market and the timing of demand. Compounding these uncertainties to the supplier is the heavy investment needed to become a supplier. In this kind of environment, the availability of suppliers may be linked to the willingness of the Government to absorb at least part of the risk, which would mean that the government must incur investment costs to develop a supplier or to introduce a competitor.

DoD has no explicit basis for deciding when to introduce competition, or even whether competition should be introduced. In fact, an assessment by Archibald, et al. of the

current state of the art seems to be regrettably true [1981: p. 52]:

> Current understanding of the competitive reprocurement process is meager. It would, for example, be an understatement to say that the determinants of post-competition price differences have not yet been identified. We are unable to discover a relatively complete list of even the <u>potential</u> determinants.

Compounding the issue is the need to increase the industrial mobilization base for advanced major weapon systems. The need for a mobilization base often calls for a dual sourcing strategy in which the government procures the needed quantity from both sources. However, no one had specified how much additional cost is justified in order to achieve this objective.

1.3.1 Economic Limits

Although dual sourcing does generate competitive pressures among firms, it does not confer the full benefits of pure price competition because of the division of the procurement quantity among a small number (as a practical matter, two) of suppliers, and the lack of competition at the "guaranteed buy" level. Coupled with the fact that a substantial amount of initial investment by both the government and the second source is often needed to establish dual source competition, the net financial advantage of dual sourcing is limited, and far from precisely predictable.

A multitude of relatively recent studies undertaken to quantify the extent of savings from dual sourcing have unfortunately produced inconclusive results. A large number of variables, including the Government's own policy decisions, may contribute to the difference in the price to be paid for the product.

1.3.2 Research Limits

A mathematical requirement for any attempt to develop a forecasting model is to have a large number of observations so that a trend can be detected. For all practical purposes, this fact poses a genuine limit to the potential for

drawing useful conclusions from major weapon systems research, as several recent studies have found.

If the value of dual-source competition cannot be measured with a reasonable degree of confidence, then defense of budgetary estimates and development of a financially sound acquisition stretegy is exceedingly difficult. Given the small available data base, the most viable solution is to identify the major price determinants that would capture the essense of pricing behavoir for a group of major weapon system suppliers. The relevant forces should be identifiable---and the basic methodology and procedures can be standardized.

1.4 A NEED FOR "WHAT IF" DRILLS

If the development of an exact forecasting formula is not feasible, the determination of the net financial advantage or disadvantage of dual sourcing depends on specific assumptions about the market environment, the contractor's business strategy and pricing behavior, the Government's policies and decisions, and a host of other factors. In this case, the credibility of the projected financial data hinges on the reasonableness of the assumptions made. Therefore, the "what if" drill can be a valuable tool in estimating the financial effects of dual sourcing. Consider three advantages.

First, decision makers are reminded of the contingent nature of the numbers. Discrepencies between the estimates and actual numbers would be easier to reconcile if the original assumptions were examined. The need for such an exercise is hinted at by ADM Seymour in his commentary on the need to improve costing credibility on Capitol Hill [1982: 28, 32].

> We always budget something less. And I'm not sure that message always sticks when we take it to Congress.

Second, as discussed earlier, dual source competition may be introduced for a wide variety of reasons other than financial. At the legislative level, competing suppliers have

been awarded contracts on grounds of fairness, even-handedness, employment, and so on. At the military department level, mobilization base and improvement in technical performance are often cited as major reasons for dual sourcing. In our view, policy issues such as fairness, employment and mobilization base do not easily render themselves to quantified analysis. However, a financial cost-benefit analysis of the dual sourcing decision, based on a known set of policy assumptions can be a valuable tool. If the result shows dual sourcing is uneconomical, the magnitude of the diseconomy can still serve as a useful input in setting Policy.

Third, conveying the assumptions made by the Government to the suppliers could minimize much of the guesswork and uncertainties faced by both parties. Such an exercise should enhance, rather than detract from, the reliability of the cost estimates.

1.5 STUDY OBJECTIVES

As discussed earlier, there are literally hundreds of factors that may influence the price paid for goods under dual sourcing. Our objectives must therefore be limited.

The objectives of this study are:

1. To develop a standardized methodology to estimate the financial consequences of dual source competition.
2. To identify significant variables that must be considered in evaluating dual-sourcing strategy.
3. To estimate a reasonable range of values for major relevant variables to facilitate estimation by practicing analysts.

In order to accomplish the objectives listed above, we will focus on the major questions facing the analyst when the second sourcing decision is contemplated.

1.5.1 Specific Research Questions

The following questions will serve as a touchstone in the selection of important variables to be considered in our analysis.

1. How do conditions of industry capacity utilization affect the competitive environment in the market, which itself is an essential element in sole-source versus dual-source decision?
2. To what extent does "gaming" activity erode the potential benefits of dual sourcing?
3. How effective is the audit and renegotiation process in stimulating the economic advantage of competition?
4. Could DoD's efforts to reduce product acqusition costs be so effective as to make the DoD market so unattractive as to effectively eliminate potential suppliers?
5. Would a reduction in the prices severly weaken the financial strength of potential suppliers?
6. Might (4) and (5) lead to higher costs in the event of a surge in requirements due to a prolonged emergency?
7. Is the additional administrative cost of dual sourcing large enough to require quantification and inclusion in the analysis?
8. Are the nonrecurring investment costs required to introduce a second source so significant as to offset potential savings from price reductions?

1.5.2 Assumptions

In this study, we will assume that dual sourcing is contemplated when the specifications have been developed and a sole-source supplier is in or will soon begin the production phase. This would exclude acquisition actions involving:

1. Parallel developments under research and development programs where two contractors are usually concurrently funded for proptotype hardware development leading to a "fly-off".
2. Obtaining an item from a new source subsequent to a default termination.
3. Component breakout, involving the decision as to whether components should be purchased by the Government directly and furnished to an end item contractor as Government Furnished Material (GFE) or purchased by the contractor (CFE).
4. The splitting of an award under invitation for bids procedures resulting from special social considerations such as Small Business or Labor Surplus Area set-asides.

1.6 STUDY APPORACH AND ORGANIZATION

The study approach used in this project is mirrored in the organization of the handbook. There are four remaining chapters. A brief description of each follows.

1.6.1 Literature Review

This study began with a thorough search of the relevant literature. Empirical works investigating potential savings from introducing competition as well as theoretical literature dealing with price competition were reviewed. This phase was essential to the identification of questions and the major variables the decision maker must consider. Many of the major variables considered in this study were previously identified in the empirical works reviewed here. However, a review of the literature in cost accounting and economics helped to identify several factors which had not been addressed in prior studies.

1.6.2 Profitability

DoD contractor profitability is very much a related issue. Some feel defense business profits are too low. So low, in fact, as to run a risk that the defense business may be converted into a "market of last resort." Others allege defense contractors earn "excessive" profits. The contradiction between these viewpoints is addressed in this section, where we study factors that influence the profitability of DoD contractors. This analysis leads to questions which were not addressed in prior studies.

1.6.3 Determinants of Price

Several recent studies have examined the costs or benefits of dual sourcing a selected group of major weapon systems. We combined these results with contractor and industry data, which were extracted from prior studies and from various other sources, for further analysis. Based on this analysis, many of the important variants of the sole source versus dual source question were addressed. The methodology needed to evaluate the financial consequence of dual sourcing is developed.

1.6.4 Implementation and Conclusions

Under the premise that any actual payoff to the Government of new knowledge is available only through its use, we explore the financial consequences of making the dual sourcing decision using a method that incorporates the major variables identified in Chapter 4. The method permits changes in parameter values to allow the decision maker the flexibility of evaluating financial consequences under different sets of assumptions, or the so-called "what if" drill.

Chapter 2
LITERATURE REVIEW

In this chapter we review the findings of the important past studies of the effects of competition on DoD acquisitions. Both empirical works investigating potential savings from introducing competition as well as theoretical literature dealing with price competition are reviewed.

Past empirical works on the costs and benefits of introducing competition may be grouped broadly into two categories: those examining the effects of competition on a specific program, and those examining a selected sample of programs. Findings from both groups have been far from conclusive. Even after adjusting for differences in measurement methods, both positive and negative savings have been found for competitively procured weapon systems which were previously procured on a sole-source basis. What can be established from these empirical works is that savings are possible from introducing competition, but losses are possible too. Unfortunately, the outcome does not appear always to be predictable. Exactly what conditions lead to savings versus losses is not known.

To resolve this uncertainty has been the major objective of no less than five comprehensive studies conducted by the Army and the Institute for Defense Analysis [U.S. Army, 1972; Zusman, et al., 1974; Lovett and Norton, 1978; Brannon, et al., 1979; Daly, et al., 1979]. These have all been attempts to identify a relationship between the expected savings from competition and potential explanatory variables. However, the results from these studies show that the magnitude and direction of the expected savings has been so variable that no simple representation of the effects of introducing competition is likely to help reduce the uncertainty faced by a decision maker.

While the total number of programs examined in the five above-mentioned studies exceeds forty, it should be pointed out that most of the data selected were not of particular value in predicting the expected savings from second sourcing major weapon systems. One reason is that most of the competitions were in the form of winner-take-all, or buy-outs. Very few cases of split-buy competition were observed. Another is that the investment cost for introducing competition was often assumed to be relatively insignificant, if not negligible, since most observed cases were mass-produced, low unit-value items. For major weapon systems, the gross savings from introducing competition must be sufficient to justify the significant costs and risks associated with competitive procurement.

Due to the constraint of a limited data base and the complexity of the issue, attempts to construct a simple, deterministic quantitative model for evaluation of the second-sourcing issue have to date been fruitless. Moreover, past studies have tended to rely upon strictly empirical methodology. That is, each analysis ignored factors such as the suppliers' different pricing strategies under different market conditions, and placed complete reliance on empirically-based constructs (such as learning curves) as the conceptual foundation for analyzing the decision.

Our approach to the issue will be to begin with the economic theory of the firm in mind. This conceptual foundation will enable us to identify the major questions and variables to be considered by a decision maker.

However, a review of the existing work will enable us to translate the theoretical questions and variables into operational terms, and to identify what has and has not been addressed. With this "decomposition" approach, we can evaluate prior works to see whether any light has been shed on the variables to be considered. The overriding concern is to seek any information that would reduce the uncertainty surrounding the influence of each variable.

Our discussion of the state-of-the-art will be organized by section, according to the following major topics:

1. Production Rates
2. Second-Source Start-Up Cost
3. Second-Source First-Piece Price
4. Effects of Competition on Learning Rates and Prices
5. Other Considerations
6. Research Methodology
7. Additional Issues Raised

2.1 PRODUCTION RATES

Acquisition experience in the DoD has shown that production rates for new military weapon systems are subject to frequent adjustment. Congressional pressure or world crisis, among many other factors, may be sufficient to alter previously planned production rates. Yet the impact on procurement costs of these rate changes is not generally understood. Empirical studies in recent years have documented cases where increases in production rate have been associated with increases, decreases, and no change in the unit production cost of weapon systems [Smith, 1976].

2.1.1 Production Rate and Cost

The theoretical foundation of a production rate impact on cost is closely related to the theory of economies of scale. However, to address the issue of the impact of production rate on program cost, one must make a subtle distinction between,

1. the extent to which a firm is utilizing its overall production capacity, and
2. the rate at which the units procured under a particular program are being produced.

The former relates, at least in theory, to production factors which serve the firm's total output and may, in aggregate, be fixed. The latter depends on the supply of one or more production factors that relate to the specific program--and are usually variable. These two phenomena are related in that they often act in concert.

To illustrate the effects of production rate on production cost, let us assume that there are three plants capable of producing the same item, say a missile. Further assume each plant would produce nothing but this particular missile. In Figure 2.1, a cost curve is shown for each plant as AUC1 (Average Unit Cost 1), AUC2, and AUC3 respectively.

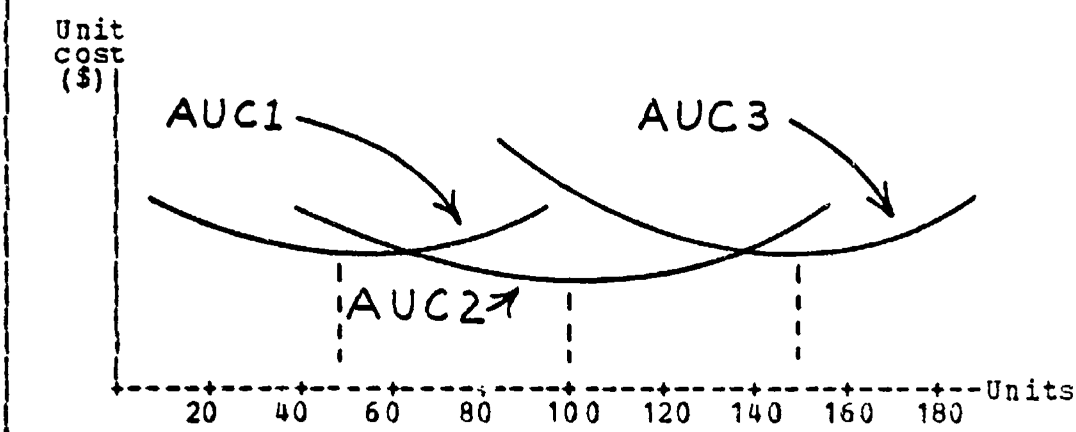

Figure 2.1: Average Unit Costs at Different Outputs

The lowest-cost production rates for the individual plants are assumed to be 50, 100, and 150 per period respectively. Plant 2 is the most efficient plant if output quantity is not a major decision factor, because it shows the lowest possible average unit cost. But if only 40 units are to be produced Plant 1 is more efficient. At 150 units Plant 3 is the more efficient. It should also be noted that 40 missiles is not the most efficient rate of output for Plant 1. It could produce at a 50-missile rate at a lower average total cost per unit than it could at 40 units.

A question which may be facing the acquisition manager is, "At what production level should the contractor's plant be facilitized?" If Plant 2 is selected as a sole source contractor, it should be facilitized to produce 100 missiles per period (at the most efficient level). Any annual buy quantity greater <u>or</u> smaller than 100 missiles will drive up the average unit cost, other things being equal.

Now assume that the sole source contractor <u>was</u> facilitized to produce 100 missiles per year, but that the annual buy turned out to be smaller than expected, say 80 missiles. If a second source is introduced, for whatever reason, and facilitized at, say 50 missiles per year, then the second source has a built-in advantage over the original source in a split-buy competition due to the impact of production rate on production cost.

2.1.2 <u>Production Rate Factor in Prior Studies</u>

Those who have addressed the impact of production rates on program cost generally agree that the production rate is a significant variable which must be included in the model when the impact of learning is to be estimated.

2.1.3 <u>Production Rate and Dual Sourcing</u>

Some analysts maintain that since dual sourcing divides the procurement quantity between two sources, it forces suppliers to forgo the economies of large scale production. As a result, unit costs necessarily rise. Inherent in this observation is an assumption that the sole-source contractor's capacity is currently underutilized and that any further reduction in production quantity (as a result of second sourcing) will drive the unit cost up along the curve--away from the optimal production quantity. This assumption may or may not be true, the reason will become clear as we discuss the results of prior empirical works later in this section.

A major point to be raised here regarding the production rate impact on unit cost is the shape of the production rate/cost curve. Most empirical works do recognize that a

U-shaped curve exists, but the models actually <u>used</u> by the analysts to capture the impacts of production rates on cost have usually not conformed to a U-shaped formulation. Bemis and Fargher [not dated. See also Womer, 1979; Bemis, 1980; Cox and Gansler, 1981.], for example, use the following model in empirical curve fitting:

$$Y = AX^{b}$$

where: Y = unit cost of product

A = a constant

X = production rate (annual buy in the example)

b = exponent describing the slope of the rate/cost curve

The equation represents an ever-decreasing unit cost when the production rate increases. The value found for b in Bemis and Fargher's study was -0.19, which corresponds to a slope of approximately 87.7% for the rate/cost curve. Figure 2.2 depicts a curve represented by such a model.

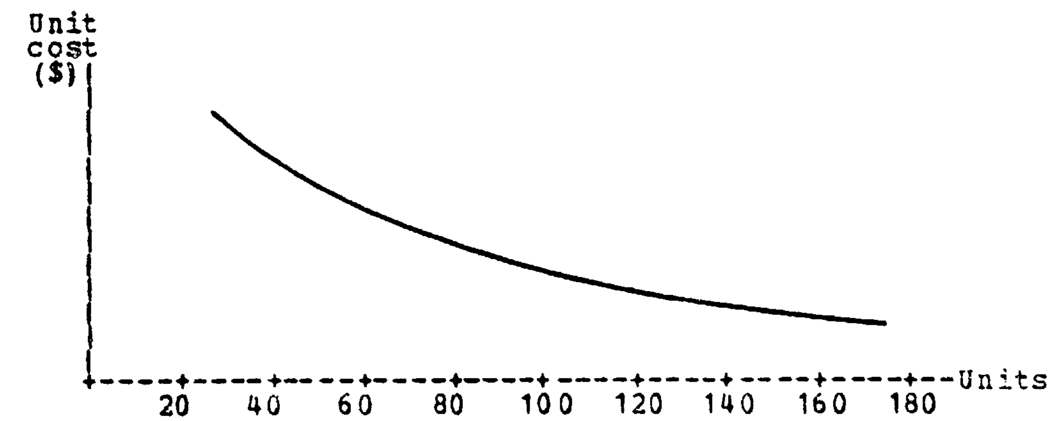

Figure 2.2: Ever-Decreasing Rate/Cost Curve

However, an ever-decreasing rate/cost curve may be a reasonable representation of reality if a firm has a great deal of idle capacity. But is this a reasonable assumption for

the general case? Carrick's [1982] interviews with five Army contractors provide some clues. He noted that some original developer/contractors and subcontractors have invested in facilities to support production rates far in excess of the actual utilization of those facilities. The Government sometimes is responsible for the the existence of excess capacity because of program cutbacks or stretch-outs. A program stretch-out increases overhead allocations which, in turn, may cause price adjustments.

Two recent analyses (TASC) [See, particularly Kratz, et al., not dated.] have in fact made the important advance of using U-shaped curves. However, their examples showed only a curve that was symmetrical, in shape, as seen in Figure 2.3.

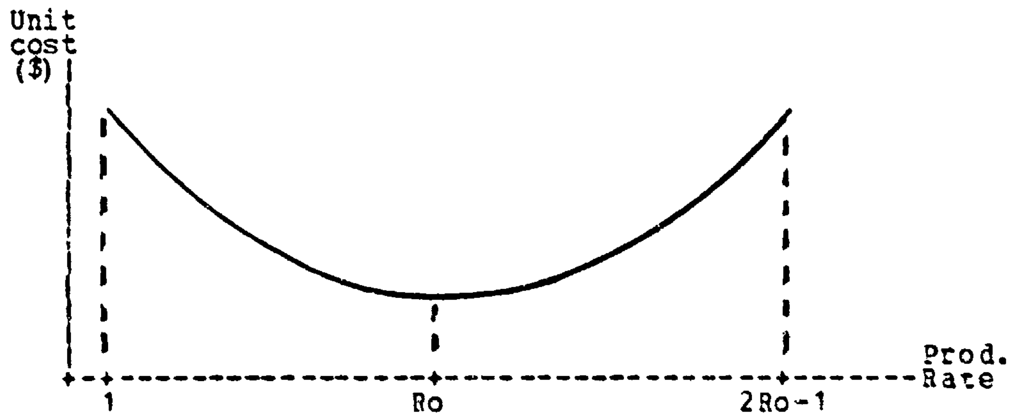

Figure 2.3: Symmetrical U-Shaped Rate/Cost Curve

The major reason for assuming a symmetrical curve was convenience, since a single production rate parameter can be added to the conventional learning curve model to reflect the impact of both learning and rate on price. The following equation expresses their U-shaped model mathematically:

$$Z = AX^{b}Y^{c}$$

where: Z = unit price of the Xth item produced

A = first unit price

X = cumulative production quantity

b = coefficient of the learning factor

Y = Rate (R) if R < Ro (optimal rate), but Y = 2Ro - R (if Ro < R < 2Ro - 1).

c = exponent describing the slope of the rate/cost curve.

Using this equation, Kratz, et al., reported the price reactions attributable to a change in production rate. Of the 11 programs analyzed, nine have a parameter value of less than 100% and two programs (Bullpup AGM-12B and TOW) have values slightly above 100%. The parameter values vary widely, ranging from a low of 75.4% to a high of 100.7%, with a mean of 90.3%. Similar wide variations in these values were reported by Smith [1976].

2.1.3.1 Weaknesses

As is the case with ever-decreasing terms, there are major deficiencies associated with assuming a symmetrical shape for the rate/cost curve. First, the optimal production rate must be accurately determined, otherwise errors may occur in both the magnitude and direction of cost changes. Second, changes in cost when the production rate is below the most efficient level may well be different from those which occur when the plant operates above its most efficient point. The former typically are the result of amortization of fixed costs over an increased number of production units, while the latter are usually the result of adding costs to "stretch" capacity.

2.1.3.2 Actual Rate Effects

We concur with the TASC analysts' observation that, in reality, the effect of production rate on unit cost may take several forms, depending on the peculiarities of an individ-

ual production line. We feel compelled to add, however, that no analysis to date has considered the effects of capacity utilization, which constitutes an important oversight, or has traced the cost/utilization curve for any firm. The optimal production rate and the shape of the curve will in fact vary from one contractor to another and, for the same contractor, from period to period. A model that allows the shape and slope to vary from case to case would be preferable.

2.1.4 Production Rate Measurement

How should we measure the production rate for cost estimation purposes? The ideal approach would be to observe the contractor's actual production schedule. Womer's study [1979] is based on an attempt (not really successful) to obtain the needed data. Virtually all other studies dealing with the production rate use lot size to produce an approximation of the production rate. Given the lack of detailed production rate data, the use of lot size does seem to be a reasonable choice for researchers. Practicing analysts may be able to do better. The implication for the program manager is that the government should require contractors to explain as part of their proposals the mechanisms for accomodating production rate changes. This point will be discussed in greater detail in another chapter.

2.2 SECOND-SOURCE START-UP COST

To introduce a second source for a major weapon system, additional investment over and above what would be necessary for a sole-source award is required. An experienced program manager is aware of the many problems that may arise in transferring a complex production technology, and of the additional costs which must be incurred to set up and manage a competitive production environment. It is difficult and expensive to get a good technical data package (TDP) for the second contractor, and even more difficult to persuade the first producer to pass along to a competitor the benefits of

his manufacturing experience. A review of prior empirical works, however, reveals that a surprisingly large number of studies have ignored the investment cost in analyzing the benefits from competition.

2.2.1 Second-Source Start-Up Costs as an Investment

There are two reasons for considering the front-end cost of introducing a second source when making the second-sourcing decision. First, the front-end costs are immediate and distinct. Unless the needed funding is specifically provided by Congress, program cut-backs or stretch-outs may be necessary to create the second source. The second reason for considering the investment cost is that the benefits from competition are long-term and uncertain. In the case of major weapon systems, the savings from introducing competition may not begin to accrue until several years after the initial investment is made. Therefore, it is important to take into account the opportunity cost of using Government funds for the front-end investment.

Among the studies reviewed, only three have taken into account the time value of money [Daly, et al., 1979; Archibald, et al., 1981; Beltramo and Jordan, 1982]. Failure to consider the front-end investment and the time value of money have given rise to unwarranted measurements of the magnitude of the net savings which may be brought about by competition. Archibald, et al. [1981], for example, say that if the in-house and external costs of introducing competition were taken into acount, and if costs and savings were duly discounted at the 10% rate suggested by OMB, the 13.7% mean GROSS savings on all post-competition production for the APRO-78 study's sample of 16 items, the net savings would in fact have been negative. Thus, the four systems examined in the APRO-79 study (750 lb. Bomb, M223 Fuze, M489 Projectile, and M103 Cartridge Case) do not seem to generate sufficient savings from split award competition to satisfy the 10% return required by OMB.

2.2.2 Elements of Second-Source Start-Up Cost

There is general agreement among analysts that the investment cost of introducing a second source should include all nonrecurring incremental costs necessary to qualify the new supplier as a competitive producer. We can classify these incremental costs in five general categories.

The cost of technological transfer: this category includes costs paid by the Government to the original developer/producer for assisting the new source, such as preparation of the technical data package, proprietary rights in data, engineering and technical service.

Special tooling, testing and production equipment: any additional unique facilities and special test equipment provided by the Government to the new source, as well as those acquired by the contractor, must be considered as part of the cost of introducing a second source.

Extra cost of educational buys: the Government must incur extra cost for awarding learning buys until the second source becomes price competitive. Note that the original source may also charge the Government a higher price due to the reduced quantities.

Administrative costs to the Government: in addition to purchasing the technical data package and contracting with the oringial source to assist the new source, the government also will incur in-house administrative costs to select the second source, verify the TDP, assist with technology transfer, qualify the new source, and administer the competition.

Logistics costs: the second source will most likely produce an end product which is somewhat different from that of the first source, either in design or components, even if both products are identical in performance. Extra logistics cost is inevitable if there is a difference between the two end items.

Some analysts also argue that the TDP tends to be inadequate for the second source either because the original supplier is unwilling to help the competitor or the technology is firm-specific. As a result, the investment cost may be

underestimated because the second source may encounter difficulty with the TDP and ask for additional compensation at a later date. Costs such as these are mainly a result of inadequate planning rather than a tangible item one must deal with before a second-sourcing decision is made.

2.2.3 Estimating Second Source Start-Up Costs

The cost of introducing a second source tends to be rather situation specific, because it consists of a wide variety of cost items which require estimation on an item by item basis. This may be one of the major reasons why prior empirical studies have most often looked at the gross savings from competition, even though analysts are aware of the need to consider this one-time front-end cost.

Before we proceed to discuss the estimation methods for individual start-up cost items, a distinction should be made between the cost to be borne by the government and the cost incurred by the contractor. The former is an investment of government funds which, as mentioned earlier, must be justified with a 10% return. The latter will be reflected in the price of the contractor's product and, therefore, should be considered when estimating the second source's price proposal. The effect on future price depends on the magnitude as well as the perceived production quantities over which they are to be amortized. Myers, et al. [1982], suggest that the proper treatment of nonrecurring costs borne by the contractor is to compute the estimated unit nonrecurring costs using a capital recovery factor applicable to the length of the contract and a "prevailing" interest rate, but a more realistic and theoretically preferable criterion would be to use the contractor's cost of capital. A firm presumably will attempt to earn, at the minimum, the average rate of return experienced by the firm. Therefore, the higher of the OMB interest rate or the contractor's average rate of return on investment may be the more reasonable rate for discounting.

As to the portion of the second-source start-up costs to be borne by the government, we will examine each cost category individually. Logistics costs--The second source will most likely produce

2.2.3.1 Cost of Technology Transfer

As mentioned earlier, costs in this general category include (a) the TDP, (b) data rights, (c) contracted technical assistance by the original source, and (d) the Government's in-house technical assistance. The complexity of the weapon system determines the size of this category of start-up costs. The first three represent payments by the government to the original developer/producer and are usually negotiated with the contractor. Therefore, the estimated costs have to come from the negotiator rather than from a mathematical equation [Daly, et al., 1979]. The price of giving up a proprietary data position (the original producer's quasi-monopolistic position) is included at this stage, and is difficult to estimate prior to negotiation. McKie maintains that the upper limit should be the lower of two costs to the buyer [1966]: (a) the cost of reverse engineering, and (b) the cost of developing alternative designs.

As to the Government's in-house technical assistance to the second source, one may argue that, unless the cost is incremental to the Government, it represents a sunk cost and is irrelevant to the investment decision. However, inasmuch as the the use of in-house technical staff represents the use of governmental resources, there is an opportunity cost involved. Therefore, it should be considered an investment, and a reasonable return is warranted. Our talks with program office personnel indicate that this is estimable on a case-by-case basis.

2.2.3.2 Special Tooling, Test, Production Equipment

This is often the largest single element of investment cost required to establish a second source. Two ways of estimating the tooling and test equipment cost have been suggested.

The first method is to base the estimate on the original producer's cost. The IDA 79 study cited the opinion of a cost analyst that the cost of special tooling and test equipment is about 80% of the amount incurred by the original source, but available data do not allow generalization of this estimate [Daly, et al., 1979]. However, it is probably safe to say that the cost to facilitate the second source should be less than for the original source. To determine a more specific number, however, requires that another issue first be resolved: at what level should the second source be facilitized? Results of interviews with program managers and contractor personnel indicate that the original source's production capacity tends to be far in excess of actual needs [Carrick, 1982]. A second source, if determined to be desirable, is most likely to be sized to some production rate smaller than the original source. Therefore, if production capacity is a question, estimating tooling and test equipment cost must take into consideration both the complexity of the system and the production capacity.

The second method calls for using "cost estimating relationships" (CERs), which relate the cost of tooling and test equipment to the production rate and hardware costs. Hardware cost is interpreted as a proxy of a measure of system complexity. The CERs developed by the Naval Weapon Center are as follows [Beltramo and Jordan, 1982]:

$$T = 0.0131C^{1.13}R^{0.44}$$

where: T = tooling and test equipment cost

C = cumulative average recurring hardware cost for 1,000 units, and

R = monthly production rate.

The estimate provided by this formula would be very rough, of course, but it represents a ballpark figure which the acquisition managers may revise according to more specific information. The formula would also be subject to further refinement as more data become available for analysis.

2.?.3.3 Extra Cost of Educational Buys

Educational buys are normally required for the second source to become a competitive supplier. The cost to the Government may not be limited to the higher production cost of the second source before it becomes competitive. Because of the reduced buy from the first source, the Government may also pay a higher price to the first source. Note that until the second source become competitive, the first source has no reason to reduce the price to meet competition. The extra costs due to the need to award educational buys may be represented by the difference between the total price of hardware paid by the government to <u>both</u> sources until competitive bidding is held, and the total price that <u>would have</u> been paid had the first source remained the sole source. There are three unknown variables involved in this computation: the first source's price reduction curve, the production-rate/cost curve of the second source, and the size of educational buys. The first two will be discussed in greater detail later in this chapter. The quantity of learning buys will be discussed now.

The second source must require only a fraction of the volume produced by the original source to reach price parity if it is to become a viable competitor. The IDA 79 study reports the experience of four missile systems regarding the size of educational buys, as shown in Table 2.1 [Daly, et al., 1979].

Based on these data, and input from program office personnel, we may say that a percentage ratio in the high 20's may be on the conservative side. A few second sources have become competitive right at the outset, but the possibility of having an instantly competitive second source must be considered an exception rather than the rule. However, if the acquisition manager has advance knowledge of such a possibility, there is no reason why price estimation should not take advantage of this information.

TABLE 2.1

Cost Parity Quantities for Four Missiles

System	Cumulative Production First	Second	Ratio
Bullpup	37,032	4,438	12%
Shillelagh	17,945	4,960	28%
TOW	11,168	2,685	24%
Sparrow	4,313	1,255	29%
		Average	23%

2.2.3.4 Administrative Costs to the Governmnet

Although acquisition managers are generally aware that additional administrative costs are inevitable when a second contractor is brought into the program, the vast majority of empirical works dealing with the costs and benefits of competition ignore these costs. There are at least two explanations for the omission. First, costs in this category are not reported separately by the Government and, therefore, are not easily identifible for analysis. Second, some administrative costs are incremental in nature while others are opportunity costs; an accurate account of opportunity costs requires a detailed analysis which, in all fairness, the analyst may not be in the best position to perform unless he or she is an especially knowledgeable member of the program office.

Estimating the additional administrative costs can probably best be done on a case-by-case, item-by-item basis. In view of the fact that a significant proportion of the costs in this category represents personnel, perhaps it is wise to define clearly the <u>incremental</u> administrative cost. Some cost items, such as testing and qualification of the second source's output, are incremental, or out-of-pocket. Under a straightforward definition of incremental cost, the cost of using in-house personnel represents the use of existing re-

sources. It may therefore be considered a sunk cost. On the other hand, if the use of in-house personnel precludes their availability for other programs, there is an opportunity cost and therefore it should be treated as an incremental cost. One must keep this difference in mind in estimating the additional administrative cost that might be required.

There is general agreement on the items to be included in the category of administrative costs. They are:

1. preparation of solicitation (RFP),
2. additional proposal costs,
3. additional costs of evaluating the price proposal by the second source,
4. testing and qualification of the second source's first unit,
5. additional personnel to coordinate the changes affecting the two suppliers,
6. extra testing and verification of delivered product, and
7. other miscellaneous additional costs such as negotiation and preparation of the additional contract, additional audit, pre-award survey, and production readiness reviews.

Some of these costs are one-time costs while others are recurring. As mentioned earlier, costs in this category have been omitted in prior quantitative studies. Therefore, there is no indication as to the magnitude of these costs.

2.2.3.5 Logistics Costs

None of the empirical studies reviewed considered the extra cost that may have to be incurred if the products supplied by different sources are not identical. Logistics costs include the costs of maintaining two sets of spare parts if they are different, the cost of having different repair facilities and technical personnel, and related support costs.

The costs of these items are probably impossible to estimate with precision before the second source is selected. Even once the second source <u>is</u> selected, estimating the logistics cost may be difficult, as it depends on just how different the end products will become. Nevertheless, the extra logistics costs are very real and may be significant. When making a decision on second sourcing, some provision for it, no matter how rough, is essential.

2.3 <u>SECOND-SOURCE FIRST-PIECE PRICE</u>

When a second source is to be introduced during the production phase, two important questions arise. First, what will the "first unit price" be for the second source? Second, how steep will the second source's price-reduction curve be? These two questions are important as they affect the quantity of educational buys which must be awarded to the second source before the second source can become truly price competitive. Answers to these questions are also essential when estimating the potential for savings in recurring costs once the competition starts. In this section, we will concentrate on the second source's first-unit price. The slope of the price-reduction curve will be addressed in the next section.

2.3.1 <u>Factors Contributing to First-Piece Price</u>

It is common for the second source to have a lower first unit price than the initial source did. Several factors may contribute to this difference.

First, the initial producibility problems may have been solved by the original source and the TDP enables the second source to avoid the same problems, at least partially. Also, the second source has the advantage of using subcontractors developed by the first source, and benefits from their learning. Third, the second source is likely to have a more realistic expectation of the total quantity, and therefore more accurate knowledge of the level of facilitation required for efficient production. Other factors in-

clude more stabilized product design, technological advances, and the competitive pressure inherent in having two sources.

2.3.2 Estimating First-Piece Price

Although the impact of the above mentioned factors on the second source's first unit price cannot be measured directly, surrogate measures have been attempted by several analysts. In the IDA 79 study, Daly, et al. [1979] assume that the second source is able to start production at a price equal to the second unit produced by the original source. This assumption, of course, is based on the view that some of the original source's learning (from producing the first unit) is transferred to the second source.

The IDA 74 study considers both the learning slope and the cumulative production quantity of the original source in attempting to predict the second source's first unit price [Zusman, et al., 1974]. Based on a few selected programs, an equation for the second source's first-piece price is derived. However, the model is not sufficiently general to be useful to the practitioner. Unless all the observations used to derive a specific equation are of homogeneous units of product, and are the same as for the intended application, the result will be misleading.

The impact of nonhomogeneous units of product on the second source's first unit price is shown by Cox and Gansler [1981]. For very complex systems, such as a guided missile frigate, the price of the first piece produced by the second source exceeded that of the initial source by approximately 9%. For the five tactical missiles examined, the first piece price from the second source was, on the average, 25% less than the first unit price of the original source. For electronic subsystems and components, the second source won the competition without learning quantities or educational buys in the majority of cases, implying that the second source became competitive right at the beginning of production phase.

2.4 EFFECTS OF COMPETITION ON LEARNING RATES AND PRICES

As mentioned above, the ability to estimate the effects of competition on price reduction rates is essential in determining the quantity of educational buys and the amount of potential savings in recurring unit cost. It is generally expected that the unit price of products will drop under competitive pressure. The size of the expected savings may be a function of three factors:

1. a one-time, probably immediate, reduction in unit price when competition begins--the so-called "shift,"
2. a continuous, or sustained reduction in price because of a steeper price-reduction curve ("rotation"), and
3. a change in unit production costs because of the reduced production rate.

The impact of production rates has been discussed earlier. In this section, we will address the issue of estimating the shift and rotation of price-reduction curves when competition is introduced.

2.4.1 Empirical Studies of "Shift"

A one-time reduction in unit price after competition is introduced may be the result of two factors. The contractor may shift to lower cost inputs, or he may adopt more efficient production technology. If cost reduction is not possible, there may be a reduction in profit. This downward "shift" in price is widely observed. However, no researcher has ever been able to pinpoint whether the "shift" is the result of profit reduction or production cost reduction. Myers, et al. emphasize the need for this distinction [1982].

This raises another issue. Could efforts to maximize savings in a program reduce a contractor's profit to a point such that the DoD market becomes so unattractive as to ef-

fectively drive off suppliers? The profitability issue will be deferred until later in this report. For now, we will concentrate on the reduction in unit price, regardless of the source of the reduction.

A rather dramatic downward shift in price was reported by Yuspeh [1976], and in the 1972 Army Electronics Command study [U.S. Army, 1972]. These studies, however, share a common methodological flaw. The last sole-source price was compared directly with the competitive price to calculate the reduction in price, without considering the effect of learning. The IDA 74 study also attributes a significant amount of savings (37%) to competition [Zusman, et al., 1974]. However, almost all of the subject items were submitted in the formally advertized IFB style of competition with more than two bidders. Therefore, the findings are not particularly relevant to program managers in charge of dual sourcing advanced weapon systems.

Results from the APRO 78 and 79 studies deserve closer examination [Lovett and Norton, 1978; Brannon, et al., 1979]. The APRO 78 study looked at 16 items with unit values ranging from less than $1,000 to over $50,000 and found an average price reduction of 13.7%. A regression equation was constructed from the data which indicates that the actual unit price (AUP) of competitive procurements can be predicted with the following:

$$\text{Log (AUP)} = 0.967118 \text{ Log (PUP)} - 0.226109 \text{ Log (ROQ)}$$

where: AUP = actual competitive unit price,

PUP = projected unit price on the sole-source price reduction curve,

ROQ = ratio of quantity procured after competition to total program quantity.

Since APRO researchers tend to take the position that the competitive slope will be the same as sole source slope, any reduction in price must be interpreted as due to a one-time, downward "shift."

A word of caution is in order before one attempts to use this equation to estimate competitive savings. Most of the subject items in the study were relatively unsophisticated, and virtually all were competed on winner-take-all or buy-out basis.

Using essentially the same methodology as APRO 78, the APRO 79 study examined four systems with a total of 22 multiple-source and winner-take-all acquisitions. The average reduction in unit price for the 22 acquisitions was 7.1%, indicating that the "shift" in multiple source award situations may not be as pronounced as with winner-take-all competition.

The magnitude of downward "shift" reported by TASC researchers averaged around 10% [Cox and Gansler, 1981; Kratz, et al., not dated].

2.4.2 Empirical Studies of "Rotation"

Along with the one-time reduction in unit price, this potential source of competitive savings constitutes the main objective of most empirical works attempting to estimate the impact of price competition in defense procurement. Unfortunately, the results are controversial.

Analysts' views on the rotation of price-reduction curves may be classified into two groups: (1) those who expect that the sole source slope will be essentially unchanged, i.e.; the same curve will apply to both sources, and (2) those who believe that the post-competition slope will be steeper than the pre-competition slope.

APRO researchers tend to assume that any impact of competition on the price-reduction rate should be negligible. As a result, they extrapolate the original sole source's price-reduction rates to competitive procurement situations. The APRO 78 and 79 studies [Lovett and Norton, 1978; Brannon, et al., 1979], and APRO's analysis of the IDA 79 study [Arvis, 1980] clearly reflect this view. Smith and Lowe [1982], also APRO researchers, found in their study that the competitive price-reduction rates tend to be steeper (but

not significanty so in a statistical sense), but that there is no correlation between competitive and sole source price-reduction curve slopes. Other analyses following this assumption include Army Missile Command's analysis of MRLS second-sourcing decision [U.S. Army, 1980] and Science Applications Inc.'s study of AIAAM second sourcing decisions [Beltramo and Jordan, 1982].

The IDA 79's attempt to develop a savings prediction model differed significantly from other comprehensive empirical studies [Daly, et al., 1979]. The attempt was to predict the slope of the price-reduction curve, on the basis of a linear regression, from the slope of the known sole-source price-reduction curve. However, the results show the two slopes to be uncorrelated. This left the researchers having to use the mean of the competitive slopes to predict the effect of competition on price-reduction rates. The average competitive slope found by Daly, et al., is 75%. If we use a "typical" sole-source slope of 87% (an average of those found by APRO 78, IDA 79, and Kratz, et al.), we may infer that the average rotation of slope of the price-reduction curve after competition is introduced is approximately 12%. One should keep in mind, however, that the items examined in these studies are mostly simple, unsophisticated systems or electronic items.

Cox and Gansler's analysis [1981] suggests a relationship between the complexity of a system and the rotation of the price improvement curve of a second source. It was found that the slope of the second source was approximately 4% steeper than that of the first source for the guided missile frigate and 5% for tactical missiles. Their data did not permit computation of price-reduction curve parameters for electronic items.

2.4.3 Are Shift and Rotation Predictable?

As mentioned earlier, the rotation and shift of price-reduction curves have been the most controversial issues in the analysis of competitive savings. None of the studies re-

viewed above was able to develop a reliable predictive model to determine the magnitude of shift and rotation of the price reduction curve for individual procurements. Although Cox and Gansler were able to suggest a different impact of competition among items of different complexity, their findings far from constitute a predictive model. Using the means of slopes to predict gross competitive savings has many weaknesses.

The IDA 79 researchers realized the futility of their attempt and stated:

> The reduction in unit price is the most difficult component to forecast. It is in fact likely that no precise and stable predictive relationship exists; there are so many dimensions of variations surrounding each procurement (e.g., technology, market conditions) that each system is to a considerable extent unique.
>
> Experience with previous systems reveals considerable variation in the realized gross savings in unit prices after competition [Daly, et al., 1979: 83].

To illustrate the sensitivity to various assumptions of the estimated savings attributed to the introduction of competition, Daly, et al., developed stylized examples in Appendix F of their report.

SAI analysts raised an issue which has not been addressed in prior empirical works. The issue relates to pricing strategies available to contractors. Once the Government reveals its intent to compete a system, the sole-source contractor may respond to the impending competition by raising its price so as to maximize profit while it can [Beltramo and Jordan, 1982]. Under this circumstance, estimating the economic effects of competition most likely will overstate the size of any available savings. This is the predictable result if the sole source contractor exercises such gaming strategy, which is a distinct possibility.

2.4.4 "<u>Optimal</u>" <u>Learning Curves</u>

TASC researchers developed an "optimal learning curve," or "best competitive curve," which is a continuous price improvement curve beginning with the noncompetitive first unit price and achieving parity with the last competitive unit

price [Cox and Gansler, 1981; Kratz, et al., not dated]. It represents what "might have been" had the original producer been under continuous competitive pressure from the outset. They state that the difference between the sole-source price-reduction curve and this "optimum" curve is the possible savings from introducing competition.

While the TASC researchers' hypothesis seems correct in theory, it ignores some of the reality of procuring advanced weapon systems. A necessary assumption for this "optimum" curve to be realistic is that the two sources are competitive at the outset--which is rather unlikely unless both sources are equal partners at the systems development stage, and neither has an edge over the other in production experience. In almost all competitions, the developer has a built-in advantage over other sources. Indeed, this is the reason for having learning buys before split award competition is held. Until the original source perceives that the second source is economically ready to compete, he still enjoys an advantageous position.

2.4.5 Pricing Strategy Effects

We may categorize an original source's pricing strategy using three different scenerios (see Figure 2.4). First, the contractor may try to make a constant percentage of profit by pricing the item according to his "true" cost function, as depicted by the line LC1.

But if the Government has not decided whether to compete the system, he may elect the "penetration pricing" strategy. This strategy calls for purposely pricing the items low at the outset to hold at bay possible competitors until it is too late for a competitor to enter the market; then he can reverse the pricing strategy and enjoy the benefits of his sole source position. LC2 depicts this scenario, which is essentially the same as the second-source strategy widely known in defense procurement circles as a "buy-in."

Finally, the contractor may have anticipated that the Government will compete the system, for whatever reason.

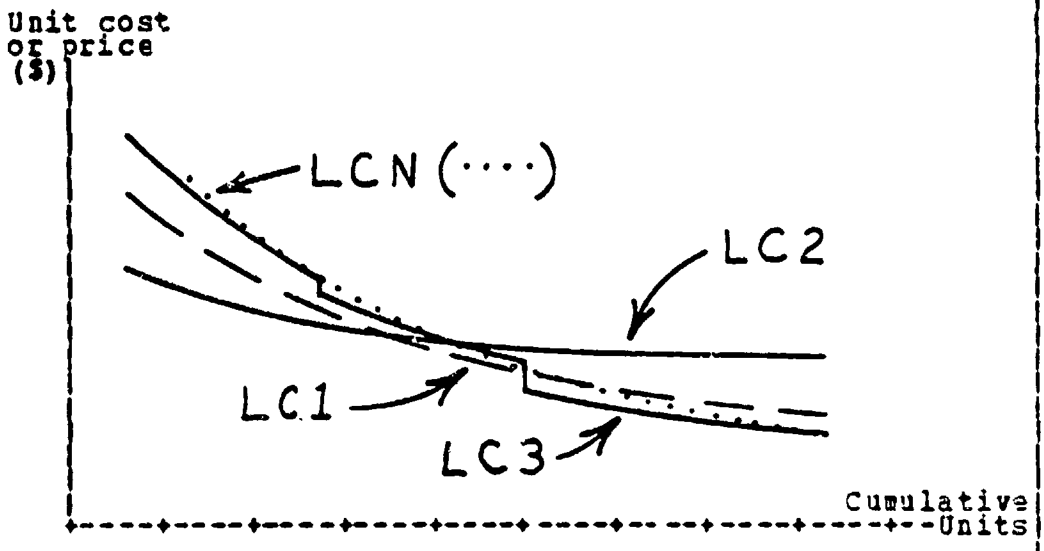

Figure 2.4: Different Pricing Strategies

Under this circumstance, a likely pricing strategy is "skimming," in which the contractor sets a high initial price to maximize profit, progressively lowering the price when necessary to lead competitor as long as he can. This is similar to the behavior hypothesized by the SAI researchers.

To illustrate, let us assume that a <u>second source</u> has been selected by the Government, and that the first unit price is lower than was the first source's, but that the second source is not immediately competitive. Let us further assume that the second source's price reduction curve is slightly steeper than the first source's, as shown by LCN. The first source's pricing path may be as depicted by LC3, which is characterized by a series of downward shifts (or rotations, or both) until the line lies close to the cost curve.

Of course, defense contractors do not have unlimited pricing flexibility. The Defense Contract Audit Agency and the Defense Acquisition Regulations impose some restrictions on the contractor's pricing flexibility. However, there are some legitimate accounting liberties that can significantly

change the "cost" of an item at any point in its production life without defying the regulations. (See Chapter 4.)

2.5 OTHER CONSIDERATIONS

The decision to introduce a second source for a major weapon system requires a prospective evaluation of the financial consequences as well as a wide variety of other factors which, by nature, do not easily lend themselves to quantified analysis. The rich literature on competition in DoD procurement covers a wide spectrum of factors and variables to be considered by the decision maker. In this section, we will discuss some of the more salient issues.

2.5.1 Barriers to Competition

Despite the general belief that price competition often results in savings, and the formal commitment by DoD to use this procurement technique whenever it is possible, only a relatively minor fraction of its procurement dollars are expended under competitive conditions. There are institutional factors as well as industry characteristics which inhibit the use of competition.

2.5.1.1 Institional Barriers

Archibald, et al., conducted a series of interviews with DoD people involved in designing and carrying out acquisition strategy in their program offices [1981]. The institutional barriers to competition, as perceived by senior program acquisition personnel, may be summarized under three headings:

1. Additional time and money needed
2. Extra management complexity and effort required
3. Lack of clear near-term benefits and incentives

The magnitude of funding needed for introducing a competitive second source tends to be large for advanced weapon systems. When substantial amounts of money are involved, the DoD and Congress must be sold on the competition. In

fact, the required front-end funding may be so significant that it may be necessary to compete with another program's very survival in order to obtain the necessary funding. Congress tends to dislike programs with heavy front-end cost. Money for competitive development programs tends to be a prime target during a budget squeeze.

Competition also tends to slow a program down because of the time involved in source selection, testing and qualification of a second source. This may be a disincentive to competition because there is usually a strong desire to deploy the system as rapidly as possible. In addition, there is a risk that the cost may rise, rather than fall, as a result of competition.

The extra management effort stems from two sources. First, if a competition is to be beneficial, considerable planning for the competitive steps is necessary, which includes the request for proposal (RFP) and the usual complications and precautions that go with it. Acquiring a good TDP is also difficult and expensive. If in-house capability to develop a TDP is not available, judging its adequacy is also difficult.

Program managers have also expressed concern that policies which put too much pressure on contractors may run the risk of driving one of the contractors out of the program, leaving the old sole-source environment after all the work and expense of qualifying the second contractor. This concern seems to reflect a view that defense business may be less attractive to contractors than commercial business. We will present evidence to support this view in a later chapter.

Finally, apart from exhortations in policy documents and the "conventional wisdom" that competition is a good procurement technique, there are few real incentives for introducing competition. The costs of competition are short-term and clear, while the benefits are long-term and uncertain. Furthermore, price reductions are difficult to prove and to measure, and may be at least partially masked by inflation.

Given a typical tenure of three years, a program manager is unlikely to be around to receive the credit for any benefits that finally materialize.

2.5.1.2 Industry Barriers

The (domestic) defense market is composed of a single buyer and a few potential suppliers. Particularly in the case of major weapon systems, attempts to bring competition into a program may be hampered by entry barriers existing in the industry. Most discussions of industry barriers have been anecdotal in nature. Our literature review did not uncover any systematic study attempting to analyze how barriers affect the Government's attempt to use price competition.

Entry barriers have been found in some studies to be related to the profitability of defense work. The profitability issue has been the subject of at least two comprehensive research projects [General Accounting Office, 1969; Profit Study Group, 1976].

We feel a more relevant contemporary question is whether industry perceives defense business to be more or less attractive than commercial business. In the final analysis, it is the number of firms attracted to the defense market that will determine the vigor of any competition which might be achieved through dual sourcing, or by any other means. Gansler, for example, cited one instance in which the 1974 Congressional action doubling tank orders ran into trouble because the only qualified supplier of steel castings refused to supply them when he found commercial business offered a more profitable use of his facilities [1980].

There seems also to be common complaint of an adversarial attitude among some defense buyers. To understand this attitude, one must examine the relationship between production costs, profits and prices in the defense business. Daly, et al., maintain that while the lack of competition may create a possibility of very high rates of return for contractors, part or all of this potential return is absorbed by larger than necessary costs [1979].

Why are defense contractors not made to be efficient? The simple existence of inefficiency does not assure the Government that competition will eliminate it. Gansler says that the defense industry is in reality regulated, and that detailed government intervention is grossly inefficient and frequently self-defeating [1980].

A pure, free market economy does not and probably can not exist in this environment of a single buyer and a small number of suppliers. Sellers observed, for example, that unused plant capacity was particularly high among firms with a high government/low commercial mix [1979]. The need for ample capacity may partly be attributed to the amount of capacity required to "win the contract," and partly to the need for "surge" capacity. Idle capacity, however, discourages investors and lenders, making it difficult for a firm to obtain financing. Unused capacity also inflates the cost of existing defense work, adding to the price the Government must pay. Therefore, while the profitability of defense work may not be high, the price paid by the Government is not necessarily low.

As one would expect, a contractor does not welcome competition. If the cooperation of the first source is needed to bring a second source on board, it is rather unlikely that the first source will give full support. Reports of inadequate TDP's are frequent. The consequences are potential claims by the second source for deficiencies in the TDP, and a delay in achieving cost parity by the second source. The contractor teaming approach used in the Joint Cruise Missile Program may remove this barrier by not creating a monopoly situation during the development phase.

2.5.2 Threat of Competition

Next to actual introduction of a second source, the threat of competition may be the best strategy the Government has available for controlling the prices of a sole source supplier [Beltramo and Jordan, 1982]. There is evidence that, even in cases where the second source never succeeds in pro-

ducing a usuable product, the pressure of potential competition on the first contractor still makes the effort worthwhile [Baumbusch, 1977]. However, a threat of competition will be most effective only when certain conditions are met. First, the Government must clearly own the data rights needed for technology transfer. Second, technologically capable suppliers must have sufficient capacity to be willing to compete.

One should note that a threat will not be effective for the entire length of a system's production phase. The reason is that once production is so far down the road that it would no longer be practical to introduce competition, the sole-source supplier will ignore the threat and revert to a sole-source pricing strategy. This scenario is similar in effect to the "penetration pricing" strategy depicted by LC2 in Figure 2.4.

2.5.3 Qualitative Benefits of Competition

Apart from generating lower recurring unit prices, there may be other significant benefits from introducing competition. Virtually every study dealing with the issue of price competition in DoD acquisition has discussed other benefits. We will simply list the more significant ones without additional discussion:

1. Enhanced mobilization base and surge capability
2. Improved product quality
3. Decreased incentive for contractor-enriching change proposals
4. Improved likelihood of meeting delivery schedules
5. More equitable acquisition processes
6. More rapid technological progress

2.5.4 Negative Aspects of Competition

Given the general wisdom that price competition is beneficial to the buyer and the official commitment to employ the technique when possible, it is not surprising to find that few negative aspects of competition are discussed in the literature. But this does not mean they do not exist.

Apart from the need for a significant amount of front-end investment, the most notable disadvantages of having two suppliers are the logistic problems and the added complexity in contract management. Another negative factor is the fact that the investment is short-term and clear while the payback is long-term and uncertain. These factors have been addressed earlier in this chapter.

Also, dual sourcing necessarily divides the quantity to be procured between two suppliers. Other things being equal, the lower lot size can increase unit cost for two reasons. If the contractor has excess capacity, a reduced demand level means the fixed costs must be born by fewer units of output. Reduced quantity also means that the contractor will not ride as far down the learning curve as would have been the case had he remained a sole producer with a larger quantity. On the other hand, if the sole source producer does not have sufficient capacity (for whatever reason) to produce the needed quantity without expanding, a reduction in the production rate could be beneficial to the Government.

Under dual sourcing, the high bidder is usually awarded a minimum sustaining quantity to maintain his competitive position. This guarranted quantity creates an opprotunity for profit maximization if one or both contractors have no desire to win the larger quantity. This pricing behavior has been observed in a number of dual sourced systems. It is apparent that price estimation models must take into account the different gaming strategies employed by contractors under different circumstances.

Finally, too much competitive pressure may drive off competitors, leaving the Government in the sole source environ-

ment again. A reduction in costs to the Government will be possible only if the contractor is willing and able to cut costs or profit, or both.

2.5.5 Necessary Requirements for Competition

Some basic requirements exist which should be met before embarking on any second-sourcing efforts. Some of these requirements have been discussed earlier in this chapter. In this section we will summarize the general, nonquantitative conditions which are conducive to successful price competition [Lamm, 1978; Nelson, 1980; Myers, McClenon and Tayloe, 1982].

First, there must be an adequate product description. The product should be describable in a rigorous fashion, so that potential suppliers can understand and comply with the Government's requirements. Second, there needs to be a good TDP. Even with the most tried and tested specifications, new sources will have some technical difficulties as a result of different production engineering approaches. It may very well happen that new sources who quote "tight" prices in competition will, subsequent to award, go over the specifications with a sharp, bright light scrubbing the package intensively in order to support deficiency claims.

It is generally considered advisable to wait unitl the item is in production to develop the TDP in order to ensure that the package is adequate and most production problems have been identified and resolved. But a counter point raised by several analysts is that competition should begin as early as possible to maximize the potential savings, and the chance of having a competitive second source as early as possible [Bemis and Pargher, undated].

Proprietary rights to certain elements of the TDP may not be the only reason for sole-source procurement, but a contractor's priprietary data position does sometimes force the buyer into a sole source position [McKie, 1966]. Direct and indirect costs of technology transfer may be prohibitively high if the Government does not own the rights.

Large enough quantities must exist to make second sourcing worthwhile for both Government and suppliers. Many items, especially advanced weapon systems, require large initial start-up costs. To justify this front-end investment, large quantities are necessary to realize savings through reductions in recurring unit costs.

In the case of advanced, sophisticated systems, it is mandatory that the Government have qualified technical personnel to evaluate the TDP, assist the second source, and coordinate technical changes initiated by either supplier.

The Government should have available at least two independent suppliers with technical competence and requisite facilities who are able and willing to compete. Problems experienced by the current contractor may be of sufficient magnitude to discourage any interest in competing. Some contractors may have adequate knowledge to compete, but may not be <u>willing</u>, due to availability of more lucrative alternatives. Second sourcing will not work if serious new sources cannot be established and the original source is keenly aware of his competitors. Sufficient lead time must be available to meet production schedule and deployment requirements. The tasks which fill this lead time include; (a) source selection, (b) first article qualification, (c) pre-award survey, and (d) learning buy awards.

2.6 <u>RESEARCH METHODOLOGY</u>

In this chapter we have reviewed virtually all of the relatively recent studies undertaken to quantify the extent to which savings are available from the competition of formerly noncompetitive procurement awards. The results of prior studies, however, are far from conclusive. Furthermore, in a majority of cases, faulty methodology or data deficiencies have diminished their usefulness. In this section, we will briefly discuss the generally recognized data and methodological deficiencies of prior empirical works [for mor detail see Arvis, 1980; Archibald, et al., 1981].

Data deficiencies result from: (1) the need to use subjective input when objective data are not available, and (2) the need to adjust, often somewhat arbitrarily, the data for consistency. Since contract data are not designed for the purpose of statistical analysis, a certain degree of data adjustment is inevitable. However, the degree of adjustment has been so extensive in some studies that the usefulness of their results must be questioned.

The first methodological deficiency, found in most early empirical studies and some relatively recent ones, is the failure to consider the effects of learning and inflation in computing the savings from introducing competition. The difference between the last sole source price and the first competitive price was considered the savings attributable to competition. These studies typically reported a very large amount of savings from introducing competition.

The second methodological deficiency may be characterized by the omission of the front-end investment costs. Some studies admitted that the second-source start-up cost should be considered by decision makers, but omitted it in the statistical analysis. Other studies, however, exhort the virtue of price competition with "evidences" of procurement savings without even mentioning that there were front-end investment requirements. Although this problem might be attributed partially to bias on the part of the researcher, the attitude of some program managers may partially be at blame as well. Results of interviews with DoD acquisition managers show that most of the interviewees consider the second sourcing effort a success if the unit price of the system is lower than was projected from an extrapolation of the original producer's price-reduction curve, or if the original producer lowers its price after competition [Parry, 1979]. It is difficult to determine whether this attitude was influenced by biased empirical works or the results of the studies were induced by this attitude.

It should be noted that those studies which separately analyzed recurring costs and nonrecurring costs found only

relatively modest savings, averaging in the range of 7% to 15% in recurring cost reduction for low value radios, missiles and components. [Lovett and Norton, 1978; Brannon, et al., 1979].

Although some of the empirical works include the front-end start-up costs in estimating savings, many left out significant elements of start-up costs for various reasons. The most frequent omissions are the cost of the TDP, the cost of the original contractor's assistance to the new source, and the cost of additional administrative effort.

Another common deficiency is the failure to discount savings. As we mentioned earlier, front-end investments are short-term while potential savings may not be realized for several years. Sound investment policy, as well as OMB direction, calls for discounting savings.

Although the effect of production rate changes on unit production cost is well known, this factor was not considered in empirical studies until quite recently. None of the comprehensive studies conducted by IDA, APRO, or the Army Electronic Command includes this factor.

Another factor that has never been addressed in prior studies is the degree of subcontracting and its impact on the chance of savings if competition is introduced. Contractors argue that, for most major systems, the prime gets only about 20% of the contract dollar, and only half of that is labor [Richardson, 1982]. Although we do not necessarily agree with this particular argument, we do believe that the extent to which common subcontractors are used by both sources should be a factor in the second sourcing decision.

Finally, with the exception of the APRO 78 study, none of the comprehensive studies was able to identify any relationship which would be useful for predictive purposes. Unfortunately, items examined by the APRO 78 study are mainly simple systems competed on a winner-take-all or buy-out basis. The result has little meaning for major systems under consideration for split-buy competition.

2.7 ADDITIONAL ISSUES RAISED

Despite the multitude of empirical studies undertaken during the past decade, there has been only a modest reduction in the uncertainty associated with estimating the savings from introducing competition to a previously sole source procurement. There have been some obvious advances. Methodologically, the use of constant dollar, the extrapolation of sole source price-reduction curves, and the inclusion of a production rate term are typical among more recent studies. The separation of the one-time "shift" from sustained curve "rotation," the inclusion of front-end investment, and discounting of future benefits are also now recognized as necessary.

Given that the magnitude of savings from competition is a function of so many factors, the limited number of case histories of major weapon systems acquisitions has apparently prevented researchers from isolating patterns of savings that would significantly reduce uncertainty. Complicating this problem is the lack of a theoretical foundation to explain the findings of empirical works.

In fact, prior works have relied upon a <u>strictly</u> empirical approach, totally ignoring the insight potential from the economist's "theory of the firm." The assessment by Archibald, et al., of the current state of the art seems to be disturbingly true [1981:52]:

> Current understanding of the competitive reprocurement process is meager. It would, for example, be an understatement to say that the determinants of post-competition price differences have not yet been identified. We are unable to discover a relatively complete list of even the <u>potential</u> determinants.

The RAND study offers the following important questions that should be addressed in studying competition in weapon systems acquisition:

1. In what circumstances does competition lead to cost reductions in production, or profit reductions, or some combination of the two?
2. Does competition influence a firm's efficiency by inducing it to invest in capital equipment, manufacturing technology, or product development? Under what circumstances?
3. How does the firm's general business situation and alternative investment strategies affect the impact of competition?

To address the first two questions, program-specific as well as contractor-specific data are needed. The third question is akin to the issue raised by SAI's researchers, Beltramo and Jordan, which is that the impact of introducing competition depends on the ability and willingness of potential suppliers to compete [1982].

Chapter 3
PROFITABILITY

Clearly, the price the Government must pay to acquire goods from a contractor serves two functions. One of these is to reimburse the contractor for the costs it must incur to supply the goods. The other is the generation of profit. Profit, of course, compensates the contractor's stockholders for the use of their funds, and for the risks they assume.

Lately, DoD-contractor profitability has been very much an issue. Some observers express alarm that low profits threaten to convert the defense business into a "market of last resort." Others allege defense contractors earn "excessive" profits. Here we explore the apparent contradiction between these viewpoints. Specifically, we examine data covering 20 years, and study how the profitability of DoD contracts has been influenced. We ask how profitable contractors are in their DoD versus commercial business segments, and whether the risk levels faced are equivalent. Our conclusion is that Program Managers (PM's) have been able to take advantage of the bargaining power they hold to buy goods at substantially lower profit margins when capacity utilization is low. The returns earned by contractors on DoD business are measurably lower than the returns on commercial business during periods of low capacity utilization. Also, the volatility of returns is higher for DoD business which means the risks are viewed by management as being somewhat higher.

3.1 CONTRACTOR PROFITS

The importance of profit to the relationship between the DoD and defense contractors is formally recognized in the Defense Acquisition Regulations [DAR 3-808.1(a)].

> It is the policy of the Department of Defense to utilize profit to stimulate efficient contract performance. Profit generally is the basic motive of business enterprise.

This profit policy is designed to insure that the best and most efficient industrial capability will continue to be attracted to DoD work. The policy recognizes that the DoD must actively compete with the commercial market to attract this capability.

3.1.1 Adequacy of Profit

Lately, though, the sufficiency (or largess) of contractor profitability has been subject to debate [Profit Study Group, 1976]. Col. J. R. Woody, for example, has reacted with alarm to reports of relatively low realized returns and generally higher risks faced by contractors [Woody, 1982]. He feels there is a chance that this situation might convert the defense business into a "market of last resort." There is also concern that if this attitude prevails among financial institutions, defense contractors may have difficulty obtaining necessary funds during periods of tight credit [Brown and Stothoff, 1976].

On the other hand, it has been widely alleged by organizations such as the General Accounting Office (GAO) that defense contractors earn "excessive" profits [U.S. Congress, 1971]. The striving for competition in weapon systems acquisition is, in large part, attributable to a growing sense of futility--a feeling that efforts to control acquisition costs through audits, negotiation and administrative pressure fail to reduce this "excessive" profit.

Much of the apparent contradiction between these viewpoints can be attributed to the difficulty researchers have in measuring the profitability of a portion of a firm's business. Thomas, for example, has shown how terribly equivocal the process of allocating corporate overhead to divisions can be [Thomas, 1969].

3.1.1.1 DoD Division "Cost"

The performance of a defense contract is often accounted for in a separate business unit (or division) of a company. This obviously means the Project Manager is interested in

just how the contractor accounts for direct costs, and in how corporate overhead and other indirect costs are allocated to divisions.

The Cost Accounting Standards Board (CASB) was established, largely at the urging of ADM Rickover, to bring uniformity and consistency to the process of determining the cost of goods produced for the Government. Even though the CASB no longer exists, its pronouncements live on by force of law. However, they have fallen somewhat short of bringing total uniformity and consistency to the accounting process. Flexibility still exists in several areas.

One example of continuing flexibility is the allocation of home office expenses. Even though Standard 403 addressed the problem, contractors can choose among at least three bases--payroll, revenue and assets--in determining the amount of cost the DoD division, and hence its products, is to absorb. Residuals are allocated by a formula. If the contractor is so motivated, the method which maximizes "cost" can be selected--legally.

Standard 410 deals with the allocation of general and administrative expenses to final cost objectives. Allowed bases include materials, payroll and overhead. Again, the one which maximizes "cost" can be selected.

The allocation of service center (a department which serves manufacturing departments but does not itself work on products, such as machine maintenance) costs is the focus of Standard 418. Here use of either the "reciprocal" or "sequential" method is allowed and, under certain circumstances, the "direct" method. Which will the contractor choose?

Finally, allocation of engineering costs is treated in Standard 420. The contractor can keep track of the amount of time spent by engineers on DoD work, and then allocate the cost directly. Otherwise, the cost can be included in an overhead pool and treated in any of the ways allowed for other overhead costs.

In short, we feel Thomas is right. So much flexibility remains that measuring the profitability of a <u>portion</u> of a

firm's business is virtually impossible. The profitability of a portion of a firm's business can be significantly altered by using different cost allocation methods. Even under a cost plus fixed fee or firm fixed price contract, the fee ascertained by the government contracting officer as reasonable does not represent the true profitability of the government contract.

3.1.2 Profit Varies with Conditions

Some of the rest of the contradiction can be attributed to the fact that the different studies have been conducted at different times, and competitive conditions change through time. There is good reason to believe the relative profitability of defense business may also vary with conditions. It is well-understood that when the economy slackens, and excess manufacturing capacity grows, (real) prices tend to drop and profit margins weaken [Shapiro and Baumol, 1970]. When demand falls, firms (particularly those with larger fixed costs) tend to engage in vigorous price competition [Ferguson, 1969]. Any positive contribution (surplus of price over direct costs) a contractor generates can help offset fixed costs. The amount of profit reduction experienced should therefore be related to the decline in capacity utilization.

3.1.3 DoD as a Large Customer

It is undeniable that the DoD is a powerful buyer. The amount of bargaining power held by program managers (PM's) is particularly great in heavily defense-oriented industries such as aerospace, where the Government usually accounts for between 40% and 60% of total sales. We therefore suggest the following:

> PM's should be in an ideal position to take advantage of lulls in capacity utilization--to drive "hard bargains," and buy goods at lower profit margins. Profits earned by contractors on DoD business should be measurably lower than profits on commercial business during periods of low capacity utilization. However, when the industry is busy--when there is sufficient total business to require utilization of a large portion of capacity--the profitability of DoD business must at least reach parity. Otherwise, industry might have no incentive to accept DoD orders.

It is this hypothesis we seek to test.

3.2 EMPIRICAL EXAMINATION

In the pages that follow, we will report on the steps taken to test the hypothesis that the state of capacity utilization in the aerospace industry is a determinant of the relative profitability of DoD business to commercial business. We concentrated on firms in the aerospace industry because aerospace firms account for the largest dollar value proportion of defense acquisitions. Included were certain firms known to be significant aerospace suppliers, but categorized by *The Value Line Investment Survey* as "multiform," "electrical" or "electronics." A representative, although not exhaustive, list of the firms included in the study is shown in Table 3.1.

We will begin with a description of the data examined. Next the topic will turn to the analytical methods used. Finally, we will discuss the results and some of the more important implications.

TABLE 3.1
Examples of Firms Studied

Boeing	Lockheed
Grumman	McDonnell Douglas
Vought	Litton
Beech	United Technologies
Teledyne	Raytheon
Hughes Aircraft	General Dynamics
General Electric	Ford Aerospace
North American Rockwell	Texas Instrument

3.2.1 Description of Data

The data examined in this study lie in two categories; corporate data and capacity utilization data. The relevant corporate data, including financial performance indicators and, for reasons soon to be made clear, the volume of DoD business, were extracted from Value Line. (Actually, Value Line indicates the percentage of each company's revenues which derive from "Government business." We used this as a surrogate for "DoD business.") Two profitability measures were catalogued--profit as a percentage of sales and profit as a percentage of net worth.

Capacility utilization information was obtained from the Federal Reserve Board. Unfortunately, capacity utilization figures for individual firms are not available. These data are therefore for the aerospace industry as a whole.

The time span covered by this analysis is the last twenty years; so all relevant data were collected for 1963 through 1982. The percentage of Government business was not reported for every firm, every year. Also, there was significant entry and exit of new and old firms during the twenty years. Neither of these factors constituted a problem, however, since each year's data set was certainly representative of

the industry, and included approximately 25 firms--a sufficient number to provide statistical confidence in the results.

3.2.2 Preliminary Analysis

As mentioned earlier, profitability of a portion of a company's business is subject to changes when allocation methods differ. Unless all firms use the same allocation methods, profits of specific segments will not be comparable. Indeed, no source of financial information routinely reports the aerospace industry's net rates of return on the specific segments of interest--DoD versus commercial. Only the amount of profit earned by the firm as a whole is available for analysis. It was therefore necessary for us to use regression analysis as a dis-aggregation technique. We will describe the procedure used and display the results.

3.2.2.1 Dis-Aggregation Regressions

For each of the twenty years, the individual firms' percentages of Government business were used as an independent variable, and the two profitability measures catalogued earlier were treated as dependent variables. Thus, 20 regressions of the form $Y = a + bX$ were produced, tracking return on sales as a function of percent of Government business through time. Another 20 regressions of the same form tracked return on net worth as a function of the same independent variable. All twenty values of "a" and "b" for both forms are shown in Table 3.2.

The sharp break in the values contained in the "a" column under "Profit on Sales" between 1968 and 1969 is due to a change in the way this percentage was calculated by Value Line. This break will turn out to be of no consequence in the analysis. Our interest will focus on ratios taken from the individual regressions. Only the ratios will be compared through time.

Each regression was next evaluated at 0% Government business and at 100% Government business. The ratio of the lat-

TABLE 3.2

Profit as Function of Government Business

Year	Profit on Sales a	b	Profit on Net Worth a	b
1963	13.30	-0.094	11.30	0.008
1964	15.00	-0.102	14.90	-0.024
1965	14.50	-0.091	15.50	-0.011
1966	12.90	-0.061	16.10	-0.012
1967	9.85	-0.040	14.80	-0.016
1968	11.90	-0.062	13.00	0.007
1969	4.58	-0.026	13.50	-0.022
1970	4.92	-0.042	14.50	-0.066
1971	3.16	-0.021	7.36	0.002
1972	4.66	-0.042	12.90	-0.094
1973	6.85	-0.074	14.00	-0.068
1974	4.86	-0.033	13.60	-0.018
1975	4.11	-0.023	11.80	-0.011
1976	5.27	-0.045	14.10	-0.007
1977	4.94	-0.017	13.10	0.069
1978	5.21	-0.008	14.60	0.052
1979	6.15	-0.014	19.10	-0.032
1980	6.64	-0.035	21.40	-0.133
1981	6.72	-0.041	20.50	-0.135
1982	5.48	-0.024	11.60	0.010

ter to the former yields the <u>relative</u> profitability of Government (DoD) business to commercial business, as indicated by the chosen return measure. Using profit on sales, for example, at 0% Government business the return is 13.3%. For 100% Government business we find the return is 13.3% - 9.4% = 3.9%, so the ratio is 3.9 to 13.3, or .29 to 1, or 29%. The generally lower profit for government business also can be seen from the negative values of "b" in Table 3.2.

3.2.2.2 Smoothing

To help reduce the volatility introduced by the accounting principle of periodicity, and to widen the time perspective associated with capacity utilization, we used a resistant time series smoother followed by a simple Hanning running average [Velleman, 1980]. Thus, the profitability ratios as calculated on both the sales and net worth bases, as well as the measure of capacity utilization, were smoothed. The smoothed data are listed in Table 3.3 below.

To interpret and illustrate the use of these regressions, at a capacity utilization rate of, say, 85%, Form 1 would tell us to expect a profitability ratio based on sales of about,

$$-34.5 + 1.00\ (85\%) = 50.5\%.$$

Form 2 would have us expect a profitability ratio based on net worth of,

$$12.8 + 0.94\ (85\%) = 92.7\%.$$

These were roughly the conditions of the mid to late sixties. But if CU were to drop to, say, 70%, we would anticipate

$$R:S = -34.5 + 1.00\ (70\%) = 35.5\%,$$

and, $$R:NW = 12.8 + 0.94\ (70\%) = 78.6\%.$$

This is more like the 1973-75 period. The reader might like to note that the smoothed capacity utilization rate in 1982 was 73.9%. The regressions predict R:S = 39.4% and R:NW = 82.3%. The actual values were R:S = 56.9%--higher than anticipated, and 79.3%--a bit lower than expected. Note that the positive coefficients indicate that contractors' demand for higher profit from government contracts increases as the industry's capacity utilization improves.

Both forms of the regression easily pass one-tailed statistical significance tests at the .05 confidence level. The T-ratio values were 1.83 for Form 1 and 1.97 for Form 2. The critical value of "T" is 1.73 with 18 degrees of freedom.

3.2.3.1 Interpretation

These regressions constitute strong statistical support for the original hypothesis that PM's are able to use their bargaining power to advantage during industry lulls in capacity utilization, but that they must reach parity with commercial business during busy periods. However, the last portion of that statement must be qualified. The DoD never reaches profit parity as measured by return on sales, so the propor-

tion of the DoD procurement dollar that goes to contractor profits is never as high as is the case for commercial buyers. The approximate smoothed capacity utilization point at which profit parity could normally be expected on a net worth basis would be 92.8%; but at no time during the last 20 years have we reached that point. This implies the 1976-78 period was abnormal.

Now we turn to an analysis of the risks faced by aerospace contractors doing business with the DoD versus commercial customers. Here the results will be less clear.

3.2.4 <u>Risk Analysis</u>

"Risk" can be defined and measured in several ways. One view is from inside the firm--through the eyes of management. This perspective of risk concerns itself with the volatility of earnings.

3.2.4.1 Volatility of Earnings

Earnings measures based on sales are generally less important to management than returns on net worth, so we will adopt the latter as our metric for risk measurement from the viewpoint of the firm.

Management must budget cash flows and exhibit appealing pictures of net income growth. These tasks are made easier if earnings are stable and predictable than if returns are volatile. All things equal, management would prefer stable returns. Said another way, if the earnings rates on a particular line of business are more volatile, management will seek a higher <u>average</u> rate of return as compensation.

We have established above that average returns (as measured on net worth) have been generally lower on DoD business during the last 20 years than the returns on commercial business have been. At this stage, however, we need to compare volatility.

Returning to the preliminary analysis, we arrayed the dis-aggregated returns on net worth for 0% Government business in one group and for 100% Government business in an-

other. Next, we calculated the standard deviations of the two groups, as indications of their volatility. The standard deviation of returns on DoD work was 4.2%; the same number for commercial business was 3.2%. Not only are returns lower for DoD business, but the risks as viewed by management are somewhat higher. This observation explains the necessity of reaching (or exceeding) parity with commercial profitability when capacity is pushed. All things equal, management's preference from a risk/return viewpoint would be for commercial work.

3.2.4.2 Stock Price Volatility

Another measurement perspective for risk is to view volatility of returns through the eyes of the financial markets: in this case, the market for equity securities. Two measures are relevant—total risk and "systematic" risk.

Total risk is simply the volatility of returns to the equities market. Value Line measures this with a "Price Stability Index" (PSI), on a scale of zero to 100. The higher the number, the more stable the firm's stock price and, therefore, total returns to the market.

The analysis method used here was to take the most recent PSI and "percent Government business" figures for the firms in the industry, and to again run a regression. The coefficient ("b") was -0.38, with a T-ratio of -2.68. This implies, for example, that if a firm's percentage of DoD business were to rise by 10%, its PSI would decline by about 3.8 points. Total risk, as seen through the financial market's eyes, is also higher.

Total risk is a relevant factor to small investors who may hold the securities of only a few firms, but institutional investors and mutual funds are able to hold shares of a sufficiently large number of companies so as to diversify away part of the risk. The portion of total risk which cannot be diversified away is termed "systematic risk" and can be measured by a stock's "beta." This measure (also reported by Value Line) indicates the extent to which the returns

from holding a particular firm's stock are correlated to the returns from holding all other securities.

Again, we ran a regression; this time to see whether "beta" can be associated with the percentage of DoD business. But here the coefficient was trivially small and statistically insignificant indicating no association.

3.2.4.3 Interpretation

The signals deriving from the risk analysis section are slightly mixed, but interpretable. It is a firm's beta which requires higher financial returns in the securities markets. We did find the betas for aerospace firms to be higher than the market average, indicating aerospace is a riskier industry, but the <u>magnitude</u> of beta was independent of the percentage of DoD work undertaken. This means that the amount of DoD business done by a firm should not have an impact on its ability to raise equity capital. This interpretation may be substantiated by the fact that the Government typically finances a portion of the funds needed by a major weapon systems contractor through government furnished equipment, progress payments, etc.

However, <u>total</u> risk was positively associated with the percentage of DoD business, meaning the ownership of high DoD-percentage firms' securities is likely to be concentrated in the hands of institutional investors. This may be a social issue.

3.3 <u>CONCLUSIONS AND IMPLICATIONS</u>

Several conclusions which have implications for acquisition management can be drawn. The real objective of this Chapter has been to examine carefully the available data so as to provide answers to the following questions:

1. Is the profitability of DoD contracts influenced by the state of capacity utilization in the industry?
2. How profitable are the major aerospace contractors in their DoD versus commercial business segments?
3. Given risk levels faced by contractors, is the return earned on DoD business equivalent to that of commercial work?

The answer to the first question is "yes." Program Managers (PM's) are able to take advantage of the large amount of bargaining power they hold to drive "hard bargains"--to buy goods at substantially lower profit margins--when capacity utilization is low, but must pay higher prices when capacity is "pushed." This causes profits to rise when the industry is busy, and to fall during slack periods.

The profits earned by contractors on DoD business are measurably lower than profits earned on commercial business--particularly during periods of low capacity utilization. Figure 3.1 reveals 1976 through 1978 to have been the only time period covered by this study during which DoD-related returns have exceeded those on commercial business. Even though DoD-related profits increase relative to commercial-work profits as capacity utilization rises, we would not normally expect the two profit rates to be equal to one another until the 92.8% point is reached (on a smoothed basis). At no time during the last 20 years has this occurred.

The lower returns found for DoD business might be acceptable if the attendant risks were lower. However, <u>none</u> of the three risk measures used shows DoD work to be less risky than commercial. In fact, management is apt to prefer commercial work because the volatility of returns on net worth is lower. Total market risk, as measured by the PSI, is also lower for firms with higher proportions of commercial

business. Beta is comparable for different weightings of the two segments, though, which implies higher average returns are not necessary to attract equity capital.

In short, there appears to be reason for concern but not for alarm. Capital generation should not be an especially difficult problem for the aerospace industry, but the distribution of the shares of stock of those firms who tend to specialize in DoD work will be more concentrated in the hands of larger investors.

The more difficult task will be to find some way to improve management's outlook on the risk/return relationship for DoD business. This might be done in either of two ways. One would be to reduce Government's voracity for "hard bargains" when industry is slow. The other is to be willing to allow higher profit levels when capacity utilization is high. Either way, we must recognize the undeniable fact that the industry's capacity utilization situation is a major determinant of the price the Government must pay for major weapon systems.

Chapter 4

DETERMINANTS OF PRICE

In the field of major weapon systems acquisition, cost estimation, always a difficult problem, is made even more arduous when the procurement is conducted under dual-source competition. "Rule of thumb" quantifications of the savings resulting from competition have been disappointingly unreliable. It is probably even fair to say that we do not yet fully understand exactly how and when competition produces savings. The research which has been done on the known histories suggests that dual sourcing of major weapon systems has resulted in added life cycle costs as often as it has produced savings [Beltramo and Jordan, 1982]. Surely this has not been intentional.

Most recent attempts to sharpen our cost estimation abilities have focused on adding a production rate term to the conventional learning curve model [Smith, 1980]. However, the magnitude (and even the direction) of the effect on total program cost of altering production rates is not always foreseeable--particularly under dual sourcing. So its inclusion in the model, while often helpful, sometimes leads the analyst astray.

In this Chapter we explore a possibility that the effect of competition on the cost of acquiring major weapon systems under dual sourcing can more reliably be estimated by substituting an industry capacity utilization concept for the production rate concept. Simply said, the hypothesis is that:

> competition produces greater savings when firms are "hungry;" when the industry is very active, dual sourcing is of little benefit as a cost reducer.

4.1 THEORETICAL BACKGROUND

Two basic economic concepts should be reviewed prior to moving into the details of the analysis. The first is that typical manufacturing organizations have average unit cost functions that are U-shaped with respect to production volume. The other is that competing firms, particularly in the durable equipment industries, tend to bid (real) selling prices down during economic slumps. We will briefly examine each of these concepts.

4.1.1 Average Unit Cost

The generality of U-shaped unit cost functions is well grounded in economic theory [Bierman and Dyckman, 1976; Brennan, 1960]. As an illustration, consider Figure 4.1. Here the firm's average unit cost is assumed to be minimized at a rate of output which requires use of about 70% of its productive capacity.

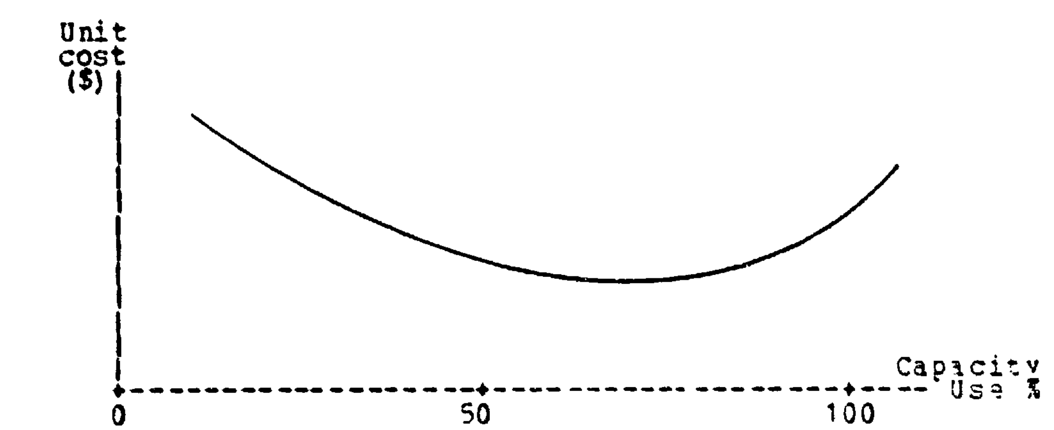

Figure 4.1: U-Shaped Average Unit Cost

The downward slope of the cost curve at lower activity levels is caused by spreading fixed costs over an increasing number of units as output rises. Eventually, however, a point is reached where diseconomies of scale begin to set in. Third-shift premiums or overtime might be required. Or

perhaps less efficient "spare" machinery is brought into use. Idle time might increase as more maintenance must be done while production is in progress. It might be necessary for the firm to increase its reliance on subcontractors. If the subcontractors' capacities are also "pushed," this could further aggravate the problem.

Production rate researchers have usually shown an awareness of the U-shaped curve [Bemis and Fargher, undated; Cox and Gansler, 1981]. Unfortunately, these same researchers have used single-parameter, ever-decreasing versions of the rate term in their empirical analyses. However, some of these works have shown positive production rate exponents, implying the data indeed came from a setting such that the firms' rates of activity placed them beyond the degree of capacity utilization associated with lowest average unit cost [Kratz, et al., undated; Smith, 1976].

In fact, the effect on unit cost of changing a firm's production rate depends on its physical facilities, its labor/capital relationship, and on the amount of other business the contractor has at the time of the change. Even the shape of the rate/cost curve, in addition to the slope, differs from case to case. Therefore no universal parameter value for the production rate impact exists.

4.1.2 Competition and Excess Capacity

When the economy slackens, and excess manufacturing capacity grows, (real) prices tend to drop and profit margins weaken [Shapiro and Baumol, 1970]. This means that if a selling price curve were superimposed on the cost curve illustrated in Figure 4.1, its minimum point would tend to lie to the left of 70%.

If demand falls even further, firms (particularly those with larger fixed costs) tend to engage in vigorous price competition [Ferguson, 1969]. Any positive contribution (selling price less direct cost) can help offset fixed costs. The result of this intense competition is that the minimum point of the selling price curve (which is the cost

curve for the buyer) lies even further to the left, and is probably <u>below</u> the cost curve, meaning the firm would be operating at a loss.

We should note that <u>without competition</u> there would be <u>no incentive</u> for the firm to lower its selling price. Therefore the ability of a buyer to take advantage of excess capacity to reduce cost is dependent on the existence of competition. Said another way, the amount of savings which can be attributed to competition should be inversely related to the state of capacity utilization in the industry.

In the preceding chapter, we have shown that the size of profit from Government contracts increases with an increase of industry capacity utilization. In this chapter, we will test to see whether capacity utilization has an impact on the final purchase price paid by DoD.

4.2 AN EMPIRICAL EXAMINATION

In the pages that follow, we report the steps we took to test the hypothesis that the state of capacity utilization in the relevant industry is useful input information for an analyst who is attempting to estimate the cost of weapons to be acquired under dual source competition. We will begin with a description of the data examined. A simple plausibility check of the hypothesis will follow. Next, the construction of the rate and capacity utilization models which were compared will be described. Finally, we will show the results obtained with the two models.

4.2.1 Description of Data

The data examined in this portion of the study lie in two categories--program data and capacity utilization data. We will briefly describe each.

The program data describe the acquisition histories of seven weapons which were dual sourced (after a brief period of sole-source procurement). These data were supplied by Science Applications, Inc. (SAI). They are listed in Appendix A. It should be emphasized that this group constitutes

the <u>entire census</u> of major weapon systems for which verifiable price data are readily available.

The prices were converted to fiscal year 1972 dollars by applying the DoD inflation index. Prices were considered more relevant than contractor cost because of the procurement perspective, and because prices capture the effects of varying amounts of profit from Government business under different market environments. Prices also reflect the effects of "gaming," which is so prevalent in dual sourcing.

Unfortunately, capacity utilization figures for individual <u>firms</u> are not available. The capacity utilization data are therefore for the areospace industry. These data were also used in the preceeding analysis of profit.

4.2.2 <u>A Preliminary Check</u>

As a simple plausibility check of the hypothesis, the data reported in Table 4.1 were assembled. The program savings (loss) data were taken from SAI's report [Beltramo and Jordan, 1982]. The capacity utilizations were averages of the <u>annual</u> figures for the aerospace industry for the years during which dual-source procurement was in effect for each program.

TABLE 4.1

A Preliminary Hypothesis Check

Procurement Program	Percent Savings or (Loss) Due to Competition	Annual Average Capacity Utilization During Dual Source Phase
TOW	26.0	63.5
Rockeye Bomb	25.5	70.9
Bullpup AGM-12B	18.7	76.2
Shillelagh Missile	(4.7)	87.0
Sparrow AIM-7F	(25.0)	81.6
MK-46 Torpedo	(30.9)	91.6
Sidewinder AIM-9D/G	(71.3)	82.3

By examining Table 4.1, the reader can confirm that SAI determined that only three of the seven programs generated sufficient savings from competition to more than offset the investments required to obtain them. (In calculating these savings, Beltramo and Jordan followed the recommended procedure of applying a 10% discount rate to the estimated cost savings, and deducting the cost to the buyer of establishing competition.) In each of the three "savings" cases, industry capacity utilization averaged less than 80% during the dual source phase of the procurement. Each time a loss resulted from competition, capacity utilization was running above 80%.

Our interpretation of this preliminary check is that it tends to support the general hypothesis. Greater savings do appear to have resulted from competition when capacity utilization was relatively low. Indeed, implementation of dual sourcing when capacity utiliz on was higher than about 80% seems to have been, in retrospect, unwise.

Encouraged by these results, we decided to go ahead with the actual modeling of a cost estimation procedure which would allow the analyst to take full advantage of capacity utilization forecasts. We felt the result of this attempt should be compared for performance with the best learning curve/production rate model we could construct using the same data and procedures.

4.2.3 The Models--General Form

The two models compared in this analysis have the following general forms:

Production rate model;

$$P = kQ^{a}R^{b}$$

Capacity utilization model;

$$P = kQ^{a}U^{c}e^{dM}e^{fN}.$$

The production rate model is conventional in form. The "Q" term represents the "mid-point" quantity associated with the particular buy. Lot size is used as a surrogate for production rate, as is the case in virtually all other studies dealing with rates. Given the lack of detailed production rate data, the use of lot size seems to be reasonable. "P," of course, is the average price for the buy, while "k," "a" and "b" are parameters.

The capacity utilization model eliminates production rate as an input and substitutes in its place "U," the smoothed utilization percentage for the industry. We used a resistant time series smoother followed by a simple Hanning running average to widen the time perspective associated with capacity utilization [see Velleman, 1980]. The term carries "c" as its parameter. In theory, utilization rates can range from 0% up to 100%, or perhaps even higher for brief periods of time. The actual smoothed data set included measures ranging from a low of 69.2% in 1960 to a high of 89.2% in 1967. For unsmoothed, individual years, the range for the annual data was 63.5% (1971) to 91.9% (1966).

Since the amount of savings presumedly depends on the form of competition in effect, two dummy mode variables were added (see "Capacity utilization model" above);

M=1 if the buy was under dual sourcing, 0 otherwise;
N=1 if competition was winner-take-all, 0 otherwise.

The parameter for M is "d:" for N, "f." Raising the constant, e, to the resulting powers causes a parallel shift in the log form of the learning curve.

4.2.4 Deriving Parameters

To place parameters on the models, we first used regression to fit a log form of the two candidate models to the data described in each of the seven acquisition histories listed in Table 4.1 and shown in Appendix A. Since these weapons were procured under dual sourcing, we derived separate models for each of the two suppliers.

4.2.4.1 The Rate Model

Taking the rate model first, we ran both simple regressions using each independent variable separately, and multiple regressions--so that the best forecasting tool each form of the model was capable of producing could be built. In most cases the rate term was not statistically associated with the price charged by the original source. However, the rate term usually was significant for the second source.

The next step was to determine parameters for the rate form of the general forecasting models, using the values derived for the individual programs. This was accomplished two ways: first by determining the median values of the parameters in question, and then by calculating the mean values with anomalous observations removed. The resulting original-source models were:

With median values;

$$P = kQ^{-0.313}R^{-0.183}$$

With mean values;

$$P = kQ^{-0.316}R^{-0.183}.$$

The second-source models were:

With median values;

$$P = kQ^{-0.323}R^{+0.560}$$

With mean values;

$$P = kQ^{-0.324}R^{+0.287}.$$

The learning rates implied by the values of "a" are all close to 80%, and the value of "b" found for the original source is amazingly close to the -0.19 value derived by Bemis and Fargher in their earlier study of aircraft data [undated]. The positive exponents for the rate term in the second-source models may seem odd; but a possible explana-

tion lies in the fact that if the second-source wins the take-out bid it, in effect, becomes a sole source <u>after</u> the dual-source comptetion is over. This event is accompanied by increases in both production rates and selling prices. It has also been suggested that the second source may be facilitized at a lower level than the original firm. It would therefore be more efficient at lower production rates, but becomes less so as rates rise [U.S. Army, 1980; Carrick, 1982].

4.2.4.2 The Capacity Utilization Model

A similar procedure was used in deriving parameters for the capacity utilization model. However, we first included all identifiable independent variables, including rate. The rate term was found to be statistically significant only once. The remaining terms therefore specified the surviving form of the model.

Only significant parameter values from the individual programs were retained. In the case of the second-source version, this meant dropping all but the "Q" and "N" variables. The models were constructed in both the median- and mean-value forms. For the original source, we found:

With median values;

$$P = kQ^{-0.278}U^{+1.250}e^{-0.201M}e^{-0.854N}.$$

With mean values;

$$P = kQ^{-0.260}U^{+1.765}e^{-0.201M}e^{-0.854N}.$$

The second-source models were:

With median values;

$$P = kQ^{-0.174}e^{-.520N}.$$

With mean values;

$$P = kQ^{-0.214}e^{-.520N}.$$

Again, the parameter values seem to make intuitive sense. The positive exponents for the capacity utilization term fit the hypothesis, and the negative coefficients for the competition mode terms imply there is a downward price shift when competition is implemented. This will be discussed in greater detail later--and will be qualified in the case of winner-take-all buy-outs.

It may at first seem odd that the exponent of "Q" is "flatter" (and more variable) for the second source than for the original. However, recall from the analysis in Chapter 2 that it is in exactly this kind of situation that pricing strategy, or gaming, plays its most prolific role. And, as discussed in Chapter 3 in a division allocation context, the Cost Accounting Standards Board (CASB) gave contractors ample opportunity to make adjustments of the "cost" of products. This flexibility extends to temporal adjustments.

Standard 409, for example, addresses depreciation methods. The contractor is allowed to elect among any of the methods normally available for financial reporting. These include (but are not limited to) straight line, declining balance, sum-of-years'-digits and depreciation by use. Such elections cause the relative costs of "earlier" versus "later" units to appear higher or lower so as to "cost justify" different pricing strategies.

The acquisition cost of materials is treated in Standard 411. The contractor can decide among LIFO, FIFO, average cost or specific identification. Each of these produces temporal differences in the cost of product during periods of changing materials costs.

Standards 414 and 417 affect the <u>cost</u> of depreciable facilities and materials, therefore increase the magnitude of the felxibility enjoyed under 409 and 411. But there are freedoms within 414 and 417 which further exacerbate the problem.

None of this is intended as a condemnation of accounting principles, or of the results of the CASB effort. We hope only make the reader aware of the relative ease with

which a contractor can "adjust" the cost of products to suit the situation, both absolutely and temporally.

4.2.5 <u>Testing the Models</u>

Due to the limited number of major weapon system histories for programs which have been dual sourced, the only available data for testing the two models' performance are the ones used for the derivations. This is not the best of research procedures, but at least it will produce an indication of the ability of the methodically derived general forecasting models to accommodate accurately the individualities of the programs.

The basic plan of the test is to use each model to forecast <u>at the onset of procurement</u> what the total procurement cost "will be" for each of the seven programs, then to compare the actual cost to the forecast. We examine only procurement cost because that is the functional purpose of both of the models under consideration. Our criteria for comparison will include means and standard deviations of both the arithmetic and absolute errors as measured by percentage cost underrun or overrun from forecast cost.

It was necessary to make some assumptions about just how the models would be used to make forecasts. To place each on an equal footing, it was assumed that the price, quantity, production rate and smoothed capacity utilization were all known for the first lot. This enabled "k" to be evaluated, as it was the last remaining term. It was further assumed that the values of the independent variables could be forecast with accuracy. This last assumption insured t at we were testing the <u>models</u>, and not the forecasting accuracy of the inputs.

The actual implementation was not difficult. First, the lot "mid-points" were calculated. The conventional formula, $((Q+1)/3)+0.5$, was used to determine the lot "mid-point" for the first lot. Lot sizes were used as surrogates for production rates as in the derivations. Smoothed capacity utilization measures were used. The dual-source mode term was

dropped ("M" set to zero) when capacity utilization was greater than 80%.

The use of the winner-take-all term requires special elaboration. We noticed from the histories, as have other researchers, that a winner-take-all, take-out bid situation seems to produce an unusually low price <u>only</u> <u>once</u>. The price rises again after the first winner-take-all buy, as the winner, in effect, becomes a sole source. This characteristic is particularly evident in the TOW and Sidewinder AIM-9D/G histories. We therefore exercised the winner-take-all term in the estimating model <u>only</u> for the <u>first</u> buy under this form of competition. After that point it was ignored. ("N" was reset to zero; i.e., the winner became a sole-source supplier.) Now consider the summary of results in Table 4.2. Clearly, the capacity utilization model has outperformed the rate model in every test.

TABLE 4.2

Summary Results of Tests

	Arithmetic Error Percentage	Absolute Error Percentage
Rate Model:		
Median Parameter Version	27.2 (93.1)	64.3 (68.6)
Mean Parameter Version	41.4 (81.7)	60.6 (66.2)
Capacity Utilization Model:		
Median Parameter Version	4.0 (38.2)	30.6 (19.8)
Mean Parameter Version	5.0 (41.4)	34.7 (18.6)

The average arithmetic and absolute errors are lower for either version of the capacity utilization model than for either version of the rate model. In addition, the lower standard deviations (shown in parentheses) indicate the pro-

gram-to-program variations of actual from forecast cost are lower under the capacity utilization model.

We view this outcome as strong support for our original hypothesis. But there are additional insights gained from the research which bear elaboration.

4.3 IMPLICATIONS OF FINDINGS

Several conclusions which have implications for both cost estimation and acquisition management can be drawn from this study. First, it seems clear that the procurement cost of major weapon systems could more closely be estimated by using a capacity utilization concept in place of the production rate concept when the procurement is conducted under competition. There is no reason to believe prices react to "hungriness" when an acquisition program is conducted without competition.

Some of the details of the analysis enable us to draw conclusions which are relevant to the way acquisition programs are managed. For example, the capacity utilization term itself was nearly always statistically significant, and in the predicted (positive) direction. We interpret this as meaning there is a price reduction in reaction to a change in capactiy utilization whenever there is a genuine threat of competition.

Others have also suggested the existance of savings from the threat of competition [including Beltramo and Jordan, 1982], but now we can quantify the effect. If we use the median model parameter value of 1.25 for the "U" term, a decline in capacity utilization from, say, 80% to 75% could be expected to produce a 7.8% price savings from the original source just as a result of the threat of competition. This gives some indication of the benefits which can be expected as a result of steps such as clear Government ownership of the technical data package.

The remainder of the analysis provided additional support for the notion that implementation of dual sourcing produces savings only when capacity utilization is less than about

80%. The dual-source mode term was significant only for Bullpup and TOW, but nearly significant for Rockeye. These were the three programs identified in Table 4.1 as having produced savings as a result of competition. The obvious conclusion is that dual sourcing should not be implemented unless utilization is expected to be that low. But the parameter value tells us to expect an 18.2% average savings from implementation under these low-utilization conditions.

The insights gained by our examination of the winner-take-all term may also have policy implications. We found the first price paid in a take-out bid situation to have been <u>much</u> lower--the parameter suggests a 57.4% savings--as participants try to "buy the market;" but that the savings do not extend beyond that first buy. The situation seems to revert to one of sole source.

We feel that knowledge of the state of capacity utilization in the industry in question is an important component to the correct management of the acquisition of major weapon systems under competition. However, we must emphasize that more research is needed to deepen our ability to use such concepts. For example, might the basic method be even more reliable if the capacity utilization measures used were firm-specific rather than composites for the industry? Are there ways to "customize" the parameters for a specific program to improve the accuracy of the forecasts? How could winner-take-all competitions more effectively be managed? Is there a way to split dual-source awards so as to take advantage of the "hungriest" of competitors? What forecasting techniques can best be employed to predict capacity utilization?

Chapter 5
IMPLEMENTATION AND CONCLUSIONS

Based on the analysis contained in Chapter 4, we conclude that knowledge of the state of capacity utilization in the aerospace industry is an important component of the correct management of acquisition programs when competition is in effect. However, more research is needed to implement these concepts with any confidence. For example, we found in Table 4.1 (reproduced as Table 5.1 below) that the economic savings or loss experienced as a result of dual sourcing can largely be explained by the state of capacity utilization during the dual-source phase of procurement. But how is one to know prior to the moment of procurement just what capacity utilization will be? It is necessary to forecast.

TABLE 5.1
A Preliminary Hypothesis Check

Procurement Program	Percent Savings or (Loss) Due to Competition	Annual Average Capacity Utilization During Dual Source Phase
TOW	26.0	63.5
Rockeye Bomb	25.5	70.9
Bullpup AGM-12B	10.7	76.2
Shillelagh Missile	(4.7)	87.0
Sparrow AIM-7F	(25.0)	81.6
MK-46 Torpedo	(30.9)	91.6
Sidewinder AIM-9D/G	(71.3)	82.3

In this final chapter we will discuss the possibility of implementation. Of specific interest will be our ability to make before-the-fact use of the "80% rule" as a practical, money-saving procurement tool.

5.1 FORECASTING CAPACITY UTILIZATION

What forecasting techniques can best be employed to predict capacity utilization? By examining the plots of monthly utilization data (Appendix B contains the data, Appendix C the plots), one can discern that the aerospace industry has experienced significant swings which seem to follow a cyclical pattern. We have shown the peaks and valleys since January, 1952, in Table 5.2.

TABLE 5.2

Swings in Monthly Capacity Utilization

Event	Date	Capacity Utilization	Interlude From Last
Peak	August 1953	92.0%	
Valley	December 1954	70.8	
Peak	March 1957	88.5	44 months
Valley	June 1960	63.7	66 months
Peak	August 1966	94.2	113 months
Valley	April 1971	61.7	130 months
Peak	November 1979	92.1	159 months

Clearly, both the peak-to-peak and the valley-to-valley interludes have grown throughout the period covered, but the averages are shown in Table 5.3. These data give testimony to (a) stable cycle extremes and (b) longer recoveries than declines.

Tables 5.2 and 5.3 leave an impression that time series methods might offer foresight. This turns out to be true, but only to a limited extent.

TABLE 5.3
Average Capacity Utilization Swings

Average Peak	91.7%
Average Valley	65.4%
Average Peak-to-Peak Interlude	105 months
Average Valley-to-Valley Interlude	98 months
Average Peak-to-Valley Interlude	37 months
Average Valley-to-Peak Interlude	68 months

5.1.1 Time Series Methods Applied

The most powerful time series models are of the Box and Jenkins family [1976]. They are capable of fitting trend, cycle and seasonal patterns of great variety to sufficiently large data sets. The particular version we used is the ARIMA, which was adapted for MINITAB by Professor W. Meeker of Iowa State University [1977].

For those who wish to duplicate our results, the version we used whenever possible was,

ARIMA (0 0 1) (0 1 1) K,

where K was the length of the last observable average interlude prior to implementation of the procurement program. When the size of the data set would not permit this form, we used a slightly weaker version,

ARIMA (0 0 1) (0 0 1) K.

These models were used to obtain a forecast of capacity utilization for each program. In each case the forecast was produced at the onset of procurement, which was then in a sole-source mode. The forecast was for aerospace industry capacity utilization at the middle of the time period during which dual-source procurement was to take place. Therefore, the forecasts were for 30 to 84 months ahead. The results, including the decisions which are indicated by blind use of the "80% rule," are given in Table 5.4.

TABLE 5.4

Forecasts of Capacity Utilization

Program	Forecasting Periods Ahead	CU Forecast	Indicated Decision
TOW	30	84.7%	Sole
Rockeye Bomb	72	79.1	Dual
Bullpup AGM-12B	54	79.4	Dual
Shillelagh Missile	30	73.5	Dual
Sparrow AIM-7F	84	80.2	Sole
MK-46 Torpedo	36	94.4	Sole
Sidewinder AIM-9D/G	48	77.9	Dual

5.1.1.1 Outcome

Since the actual decisions, of course, were to dual source, we can compare the effect of using the capacity utilization concept as implemented through a pre-program time series forecast by quantifying the impact on the cost of the three changed decisions. This is done in Table 5.5.

TABLE 5.5

Outcomes Using the Model

Program	Percent Gain (Loss)	FY72$ Gain (Loss)
TOW	(26.0)	(93.7)
Sparrow AIM-7F	25.0	101.9
MK-46 Torpedo	30.9	106.0
	Total Gain	114.2

Some explanation of the information contained in Table 5.5 is required. First, the outcome would change only if the decision regarding dual-sourcing were to change. A decision change resulted only for TOW, Sparrow and the MK-46 programs. In the case of TOW this was unfortunate. The "correct" decision, dual source, was in fact made, but the use of the time-series forecast and the 80% rule would have

produced a sub-optimal, sole-source decision. The consequence of this mistake would have been to forgo the 26% savings SAI estimated to have actually resulted from dual-sourcing this program. Based on procurement costs, this works out to a FY72$93.7 million opportunity loss. This loss "resulted" from a failure of relatively simple time-series methods to forecast the deep industry slump which occurred in 1971--the exact time period during which TOW was dual sourced. However, the outcome would have been beneficial for the Sparrow and MK-46 programs. More than FY72$200 million in losses could have been avoided.

It should be pointed out that the method made wrong decisions in the cases of the Shillelagh and Sidewinder programs as well, but these were the actual decisions and therefore do not constitute an incremental loss.

In summary, we find the time-series concept (as implemented) to be disappointingly unreliable as an implementation tool even though application of the method would have saved a net of more than FY72$100 million on these seven programs. Three of the seven "decisions" were wrong.

5.1.1.2 Improvements Needed

We feel it would be necessary to make improvements in our ability to forecast aerospace capacity utilization before it could actually be used as a decision variable. However, the methods we applied were no more than very tentative and exploratory. There are many ways of forecasting the movement of economic indicators [see Nelson, 1973]. Surely further research effort could vastly improve this key step to experiencing the savings which are achievable.

5.2 OTHER IMPLEMENTATION ISSUES

The forecasting of capacity utilization is but one aspect of the total implementation process. The parameters of the model must be quantified as well.

The analysis in Chapter 4 showed that the capacity utilization model "fits" the data for the seven programs better

produced a sub-optimal, sole-source decision. The consequence of this mistake would have been to forgo the 26% savings SAI estimated to have actually resulted from dual-sourcing this program. Based on procurement costs, this works out to a FY72$93.7 million opportunity loss. This loss "resulted" from a failure of relatively simple time-series methods to forecast the deep industry slump which occurred in 1971--the exact time period during which TOW was dual sourced. However, the outcome would have been beneficial for the Sparrow and MK-46 programs. More than FY72$200 million in losses could have been avoided.

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The analysis in Chapter 4 showed that the capacity utilization model "fits" the data for the seven programs better

than the fit achieved with the production rate model. This means an analyst faced with the task of quantifying parameters would be left with less statistical "noise" if that analyst were fitting the capacity utilization model. This, in turn, means it would be easier to make a highly confident statement about the slope of the learning or price-reduction rate curve through the capacity utilization model than with the rate model. The knowledge gained would be useful for making correct comparisons of the performance of vying contractors.

We should also point out that our model includes terms which explicitly impound the effects of (a) moving to the dual-source environment and (b) initiation of a winner-take-all take-out. The parameteric evaluation process should itself be beneficial.

Once the model is built, the parameter values could be altered to study the effects of, for example, trading off the benefits of competition against the increased learning value of buying larger quantities from a sole source when future conditions are uncertain. What-if drills of this nature aid in anticipating unusual outcomes and other anomalous events.

Some with whom we have discussed the results of our work have pointed out that the model could be improved by using the capacity utilization measures for particualr firms rather than for the industry. We totally agree, and would like to explore this improvement, but the data are not available. In the meantime, we have a model that works, and we must rely on the judgement of the analyst to alter the conclusions depending on the condition of the individual firms involved in the competition. Along these lines, we must remind the analyst that no model can ever substitute for experienced, human judgement. For example, a Box-Jenkins model could not foresee the 1971 downturn, but many human analysts did. The results of <u>any</u> quantitative model should serve only as information for an experienced, professional analyst to use in recommending a decision. For a major

weapon system which costs hundreds of millions of dollars, no analyst is going to rely on a single quantitative model which employs only a few explanatory variables. A detailed breakdown method of cost estimation is still the basic foundation of cost estimation for major weapon systems. Our model, however, may be viewed and used as a "scoping" device to examine the most likely outcome under given market conditions. This important consideration has to date been ignored.

Also, none of this is intended to suggest that economic considerations are paramount. As indicated earlier, there are often other, very valid reasons for implementing dual sourcing: such as mobilization base or the achievement of social goals. Our assumption is simply that we would like to know what it costs to achieve these other objectives.

5.3 EXERCISING RESTRAINT

In Chapter 3 we addressed the profitability of Government versus commercial business in response to those who have expressed alarm that low profits threaten to convert the defense business into a "market of last resort." The principal conclusion of our research is that Program Managers should be able to take advantage of their knowledge of capacity utilization to increase the bargaining power they now hold. The returns earned by contractors on DoD business are already measurably lower than the returns on commercial business during periods of low capacity utilization. Also, the volatility of returns is higher for DoD business, which means the risks are viewed by management as being somewhat higher.

It is undeniable that the DoD is a powerful buyer. The amount of bargaining power held by program managers is particularly great in heavily defense-oriented industries such as aerospace, where the Government usually accounts for between 40% and 60% of total sales. We therefore suggest the following:

1. PM's should act responsibly. They should resist the natural temptation to take overzealous advantage of lulls in capacity utilization--to drive "hard bargains," and buy goods at very low profit margins.

2. Ways should be found to improve management's view of the risk/return relationship for DoD business. Perhaps a guarantee of some minimum level of profit would be appropriate--or higher allowed profit levels when capacity utilization is high.

5.4 ASSUMPTIONS FOLLOWED

Throughout this analysis we have followed both explicitly and implicitly certain assumptions it might be well to review. In brief, these are as follows.

5.4.1 Assumed DoD Objectives

The following has been assumed with respect to DoD behavior and views.

5.4.1.1 Reasonable Rates of Return

The DoD understands the improtant role profits play (a) in maintaining the efficiency and strength of private industry, and (b) in providing incentive for contractors to perform services beneficial to the Government. In recognition of the importance of profits, DoD seeks to sustain an environment in which an efficient contractor can earn a reasonable rate of return while performing services for the Government.

However, the DoD is responsible to the taxpayers. It must therefore protect against buying practices which might be wasteful of Government resources. It seeks neither to reward inefficiency nor to provide contractors with unnecessarily high rates of return.

5.4.1.2 Mobilization Base

In the event of a National emergency, the acquisition requirements of DoD are likely to be considerably higher than under peacetime conditions. Since DoD's responsibilities to safeguard the security of the Nation would continue under

any circumstances, it is desirable to ensure the continuity of an industrial base sufficient to meet any reasonably foreseeable emergency.

An acquisition practice which resulted in small program cost savings without considering the factor of mobilization base might rightfully be rejected as imprudent. The economic consequences of proposed acquisition practices are therefore incomplete (albeit important) indicators of desirability.

5.4.1.3 Economic Analysis is Essential

Although the avowed reason for having competiting suppliers is to bring down the cost to the government, competition may be introduced for a wide variety of reasons other than financial. At the legislative level, competing suppliers have been awarded contracts on grounds of fairness, even-handedness, employment, etc. At the military department level, mobilization base and improvement in technical performance are often cited as major reasons for dual sourcing. In our view, fairness, employment and mobilization base are policy issues which, by nature, do not render themselves to quantified analysis.

However, a financial cost-benefit analysis of the dual sourcing decision remains a useful tool for decision makers. Even if the result shows dual sourcing is uneconomical, the magnitude of the cost serves as useful input for the decision maker in setting policies.

5.4.1.4 Advantage of Efficiency

An efficient group of contractors is able to (a) produce a given requirement with lower consumption of taxpayer resources and/or (b) produce a larger requirement with a given level of resource consumption. Both these chacteristics are desirable from the perspective of the DoD.

The mandate DoD has to protect against buying practices which might be wasteful of Government resources is facilitated by the existance of a supplier group which can mini-

mize the resource consumption necessary to meet a given requirement. DoD's responsibility to protect the Nation under any circumstances is facilitated by contractors who are able to produce large requirements with given levels of resources.

5.4.1.5 Discounted Constant Dollars

Due to changes in the purchasing power of the dollar, costs should be adjusted to constant dollars when comparing acquisition practices. Since funding for acquisitions is concurrent with expenditures which, in turn, are normally concurrent with the fulfillment of requirements, it is normally necessary to discount expenditures to present value when evaluating proposed acquisition practices.

DoD acquisitions present some of the characteristics of executory contracts in that funding and expenditures are concurrent with the fulfillment of the requirement. DoD has neither the authority nor the means to make significant temporal adjustments in its funding. Therefore, discounted constant dollar program cost is the most relevant economic measure of an acquisition practice.

5.4.1.6 Dual Sourcing is Only One Tool

Government has many possible means of controlling the cost of its acquisition activities. The implementation of dual sourcing is only one of these. Its use may or may not be necessary or desirable, depending on the circumstances.

Dual sourcing is sometimes the best tool for DoD to bring to bear in attempting to reduce the acquition cost of a particular requirement. However, implementation is neither always necessary nor always economically advantageous for DoD. Depending on the circumstances, other tools may be more advantageous, more effective and/or more efficient in achieving the desired effect.

5.4.2 Contractor Strategy and Behavior

We presume contractors exhibit behavior patterns and adopt strategies which reflect the following.

5.4.2.1 Pricing Flexibility

Unless the procurement is to be conducted in a one-shot contract situation where the total quantity is to be awarded all at once, both the prime and the second source expect orders for some minimum quantity for the duration of the program. Given this expectation, the supplier has the flexibility of proposing a high initial price and steep price reduction curve or lower initial price and flat price reduction curve, depending on which strategy is more advantageous to the firm.

5.4.2.2 To Win or Not To Win?

It is naive to assume that contractors always attempt to capture the larger share of an annual buy. Several studies have shown production rate to be a major factor in determining contract cost. But one cannot assume that economy of scale always follows large quantities of production. If one (or both) contractor has limited capacity, it may be more advantageous to be the loser in a dual-source program.

5.4.2.3 Gaming is Possible

One must accept the fact that, in a dual source competition, there is no price competition whatsoever at a guaranteed loser's share level. Results of studies have shown that at this level the offered prices were loaded. If this lower quantity is more advantageous to either contractor, the respective bid will be high. If it is more advantageous to both, a two-player gaming situation exists and the effect of price competition disappears.

5.4.2.4 Incumbent Discourages Competition

A sole source supplier enjoys a certain degree of freedom in production and price negotiations. Therefore, the incumbent

has the incentive to discourage the introduction of competition. As discussed above, the lowering of prices of early lots is a feasible strategy.

5.4.2.5 Objective is Return on Net Worth

Although there have been criticisms of the profit maximization assumption, recent studies have shown that a number of criteria are just different forms of profit maximization on a long term basis.

5.4.2.6 Cost Allocation Complicates Measurement

Although the Cost Accounting Standard Board prescribed the way indirect costs are to be allocated, considerable flexibility remains in the selection of cost pools, allocation basis, and the classification of costs. The same set of production costs incurred by a contractor could result in entirely different amounts of cost being allocated to the same final cost object, depending on different, but permitted, ways of making the allocations.

5.5 CONCLUSIONS

The research effort discussed here was funded under ONR grant No. N0001483WR30236, dated 28 December 1982. The Statement of Work which specified the task to be accomplished read as follows:

> Market environments relevant to the sole source versus dual source decision for the procurement of major weapon systems will be identified. The pricing behavior of contractors operating in these environments will be analyzed, and its potential impact on program cost will be studied. Suitable data from NAVAIR's contract file will be used, if appropriate, for empirical verification. The objective is to derive an optimal acquisition strategy for the various market environments.

We indeed have identified market environments relevant to the sole source versus dual source decision for the procurement of major weapon systems. Our most important finding is that the state of capacity utilization in the aerospace industry is a highly relevant aspect of the environment.

The pricing behavior of contractors operating under different degrees of "busyness" was analyzed, and its impact on program cost was studied. The environment's impact on contractor profitability was also studied.

Historical data from seven major weapon systems acquisitions (shown in Appendix A) were used for empirical verification. The empirical analysis gave strong statistical creditability to the hypotheses tested.

The results of the study point the way for development and implementation of superior acquisition strategies. The strategies which should follow will be applicable to various market environments.

Appendix A

PROGRAM HISTORIES

Table . TOW.

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit TY$	Average Cost per Unit FY72$
Hughes	SS	69	5,350		5,750
Chrysler	SS	69	200		20,903
Hughes	SS	70	10,400		5,567
Hughes	SS	71	2,500		4,460
Chrysler	SS	71	2,685		5,851
Hughes	CSB	71	6,500		3,904
Chrysler	CSB	71	4,000		4,437
Hughes	W	72	12,000		2,195
Hughes	W	73	12,000		2,262
Hughes	W	74	12,000		2,240
Hughes	W	75	10,837		2,219

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . Rockeye Bomb

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit FY70$	Average Cost per Unit FY72$
Honeywell	SS	67	535	8,021	8,807
Honeywell	SS	68	4,270	4,470	4,908
Honeywell	SS	69	7,150	3,121	3,427
Honeywell	SS	70	18,100	2,344	2,574
Honeywell	SS	70	5,800	2,309	2,535
Honeywell	SS	72	18,058	1,882	2,056
Honeywell	CSB	72	9,029	1,738	1,908
Marquardt	CSB	72	5,000	1,641	1,802
Honeywell	CSB	72	13,431	1,769	1,942
Marquardt	CSB	72	2,500	1,606	1,763
Honeywell	CSB	72	4,000	1,602	1,759
Marquardt	CSB	72	4,500	1,606	1,763
Honeywell	CSB	73	2,500	1,540	1,691
Marquardt	CSB	73	3,500	1,734	1,904
Honeywell	CSB	73	28,098	1,540	1,691

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . Bullpup AGM-12B Guidance and Control.

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit TY$	FY72$
Martin Co.	SS	58	700	12,040	16,158
Martin Co.	SS	59	3,015	6,687	8,753
Martin Co.	SS	60	3,805	4,987	6,583
Martin Co.	SS	61	3,375	3,802	4,920
Martin Co.	CSB	61	1,078	2,848	3,685
Maxson Co.	CSB	61	200	4,760	6,159
Martin Co.	CSB	62	6,363	2,544	3,330
Martin Co.	CSB	62	9,541	2,448	3,204
Maxson Co.	CSB	62	1,000	2,602	3,406
Martin Co.	CSB	63	6,355	2,047	2,675
Martin Co.	CSB	63	2,800	2,047	2,675
Maxson Co.	CSB	63	3,238	2,548	3,330
Maxson Co.	W	64	3,580	1,227	1,594

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . Shillelagh Missile.

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit TY$	Average Cost per Unit FY72$
Philco Ford	SS	66	1,393	12,484	15,568
Philco Ford	SS	67	16,552	3,970	4,839
Martin Marietta	SS	67	4,960	2,649	3,229
Philco Ford	CSB	68	21,846	2,531	3,014
Martin Marietta	CSB	68	7,540	2,287	2,724
Philco Ford	W	69	35,903	1,814	2,088

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . Sparrow AIM-7F Guidance and Control.

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost Per Unit	
				TY$K	FY77$K
Raytheon	SS	72	100	279.4	415.8
Raytheon	SS	73/74	225	155.6	212.0
General Dynamics	SS	74	15	700.0	916.5
Raytheon	SS	75	600	95.0	111.6
General Dynamics	SS	75	70	198.4	233.2
Raytheon	SS	76	880	88.0	94.7
General Dynamics	SS	76	210	121.0	130.2
Raytheon	CSB	77	1,100	75.0	75.0
General Dynamics	CSB	77	210	107.0	107.0
Raytheon	CSB	78	1,400	69.7	65.1
General Dynamics	CSB	78	750	83.0	77.5
Raytheon	CSB	79	900	72.5	62.1
General Dynamics	CSB	79	1,310	61.1	52.4
Raytheon	CSB	80	1,144	68.6	53.5
General Dynamics	CSB	80	300	87.9	68.6

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . MK-46 Torpedo (Airframe and Guidance).

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit TY$	Average Cost per Unit FY72$
Aerojet	SS	64	100 (Proto)	--	--
Aerojet	SS	64	470	54,100	70,276
Aerojet	SS	65	1,180	31,700	40,227
Aerojet	CSB	66	100	31,700	39,530
Honeywell	CSB	66	100	--	--
Aerojet	CSB	66	2,500	20,700	25,813
Honeywell	CSB	66	1,000	35,392	44,134
Aerojet	CSB	67	1,300	33,500	40,837
Honeywell	CSB	67	2,298	30,658	37,372
Honeywell	W	69	1,500	31,109	35,806
Honeywell	W	69	1,698	25,325	29,149

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Table . Sidewinder AIM-9D/G Guidance and Control.

Contractor	Type Procurement*	FY	Lot Quantity	Average Cost per Unit TY$	Average Cost per Unit FY72$
Philco Ford	SS	60	50	9,709	12,816
Philco Ford	SS	61	28	5,576	7,215
Philco Ford	SS	61	29	5,576	7,215
Philco Ford	SS	61	18	5,576	7,215
Philco Ford	SS	61	108	7,489	9,691
Philco Ford	SS	61	192	4,033	5,219
Philco Ford	CSB	63	300	10,541	13,777
Raytheon Co.	CSB	63	1,475	3,398	4,441
Philco Ford	CSB	63	50	13,228	17,289
Raytheon Co.	CSB	64	945	3,386	4,398
Raytheon Co.	W	66	1,280	3,767	4,697
Raytheon Co.	W	67	640	6,978	8,506
Raytheon Co.	W	68	650	6,530	7,777
Raytheon Co.	W	69	1,732	6,368	7,330
Raytheon Co.	W	70	1,000	7,134	7,833
Raytheon Co.	W	71	1,458	7,915	8,216

*SS = Sole Source; CSB = Competitive Split Buy; W = Winner-Take-All.

Appendix B
AEROSPACE CAPACITY UTILIZATION HISTORY

MO.	CY48	CY49	CY50	CY51	CY52	CY53
JAN	39.1	40.2	32.1	46.2	70.0	91.2
FEB	38.6	41.2	32.1	48.2	71.6	91.2
MAR	38.9	41.3	31.8	50.6	73.5	91.2
APR	39.4	40.2	31.9	52.6	74.2	91.0
MAY	38.8	39.7	33.8	53.5	77.7	90.9
JUN	39.1	39.0	35.0	55.0	79.7	90.5
JUL	38.8	38.5	36.1	55.7	81.1	91.7
AUG	39.6	35.6	40.1	57.4	82.9	92.0
SEP	39.9	36.6	40.5	59.0	82.3	90.4
OCT	40.5	34.7	41.9	59.5	86.3	90.3
NOV	40.1	34.1	43.4	65.3	86.7	84.3
DEC	40.4	32.9	44.6	67.1	89.6	83.6

MO.	CY54	CY55	CY56	CY57	CY58	CY59
JAN	82.1	71.1	74.6	87.0	73.0	70.1
FEB	80.1	70.9	75.6	88.2	70.6	70.2
MAR	78.9	70.9	75.5	88.5	70.4	69.4
APR	76.7	71.4	76.4	88.2	69.0	71.1
MAY	75.8	73.0	77.9	86.2	67.9	71.8
JUN	74.5	71.7	78.1	87.0	68.0	72.1
JUL	73.5	72.3	79.5	85.6	67.9	73.3
AUG	72.5	72.5	79.8	84.6	68.7	72.6
SEP	72.2	72.9	79.1	82.2	69.3	69.2
OCT	71.1	74.4	82.1	79.9	69.4	68.6
NOV	70.8	74.1	84.6	76.0	70.6	68.6
DEC	70.8	74.7	86.3	73.5	70.6	68.5

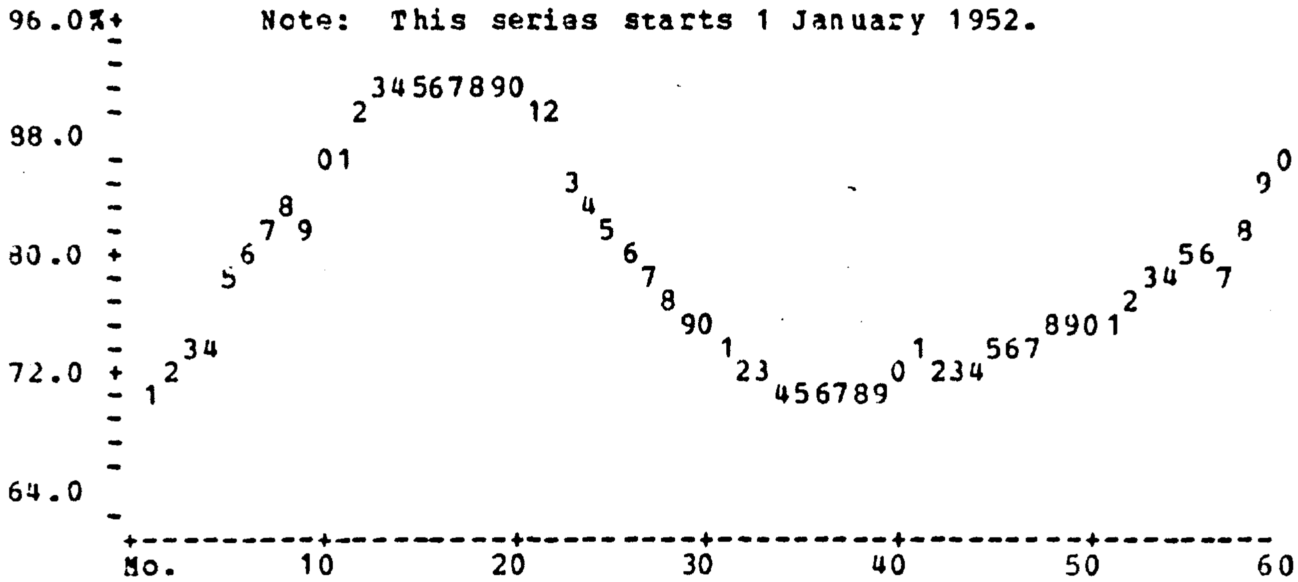
MO.	CY60	CY61	CY62	CY63	CY64	CY65
JAN	67.9	66.4	71.9	84.8	82.3	81.4
FEB	68.7	65.4	74.0	84.2	82.8	80.9
MAR	67.9	66.6	75.0	83.6	82.6	80.9
APR	67.9	67.0	75.1	82.7	82.9	81.4
MAY	69.5	67.5	76.1	80.5	83.3	83.3
JUN	63.7	67.0	77.0	82.4	82.0	82.9
JUL	66.3	67.1	78.6	83.0	80.6	83.4
AUG	66.3	67.8	79.5	83.5	80.4	83.8
SEP	66.0	70.2	79.3	83.9	80.3	84.8
OCT	66.8	70.5	79.7	83.5	80.3	86.5
NOV	66.0	72.2	79.8	82.1	81.4	87.4
DEC	65.9	72.6	80.1	82.0	81.0	88.4

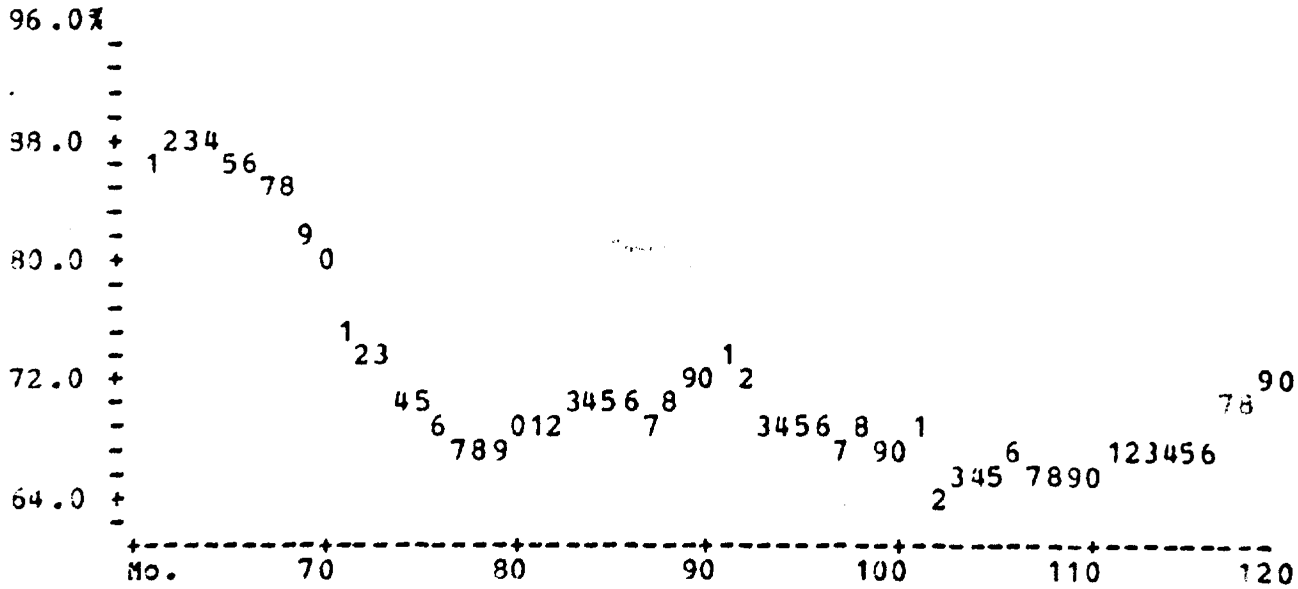
MO.	CY66	CY67	CY68	CY69	CY70	CY71
JAN	91.6	92.6	89.1	83.5	76.0	64.8
FEB	90.2	91.4	90.4	82.7	74.6	63.5
MAR	90.6	92.3	89.0	84.1	73.8	62.5
ARP	90.0	93.2	86.3	83.5	73.0	61.7
MAY	90.9	92.2	87.7	83.6	69.8	63.4
JUN	90.1	92.0	88.7	82.1	69.3	63.4
JUL	92.7	90.3	88.1	82.6	69.3	63.1
AUG	94.2	90.7	86.6	82.3	68.2	63.4
SEP	92.0	90.2	85.8	82.7	67.5	63.8
OCT	93.3	90.0	84.5	82.1	65.6	65.1
NOV	93.1	89.5	84.3	80.0	65.8	63.5
DEC	93.1	90.4	83.7	78.1	65.0	63.6

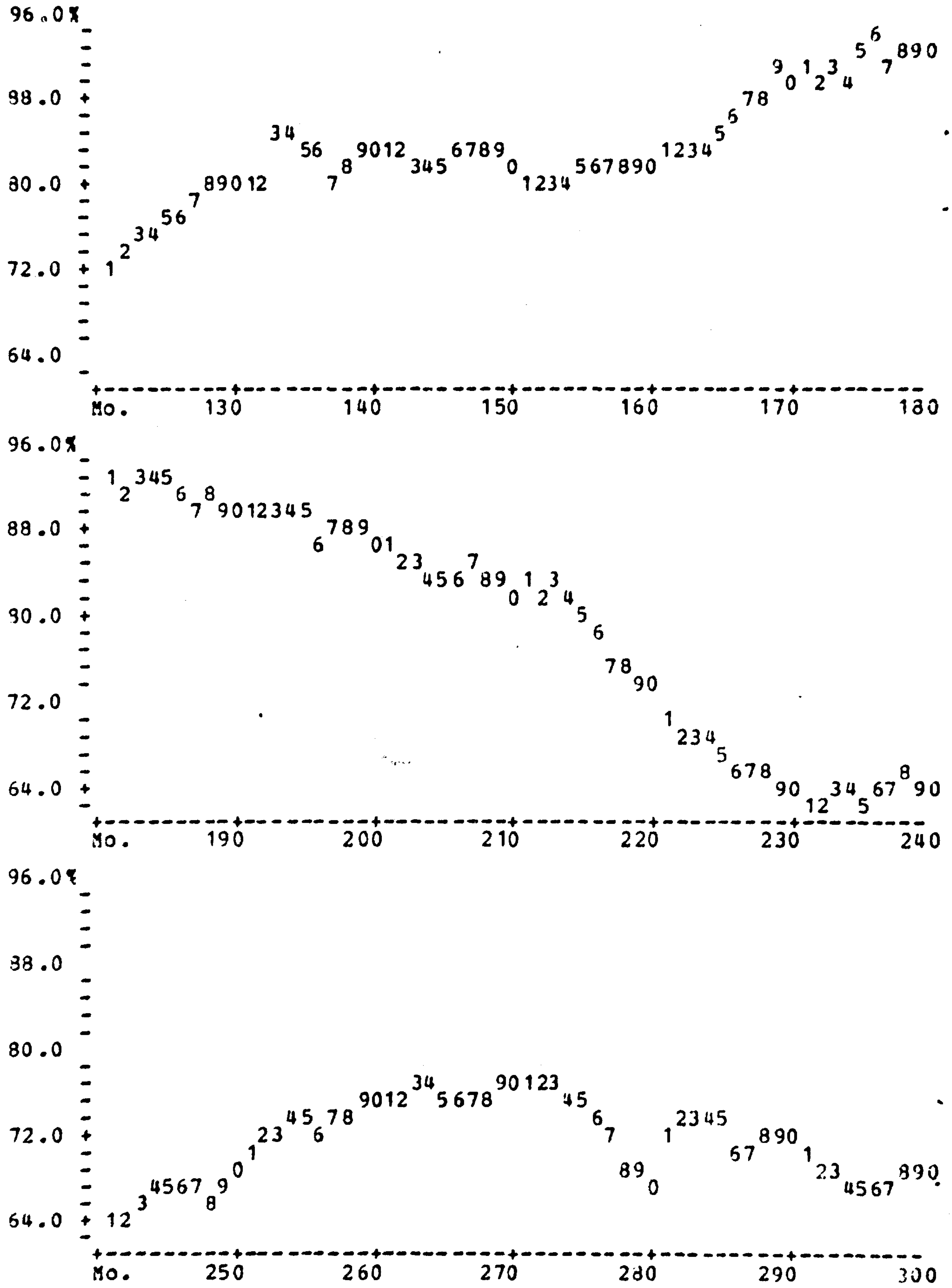
MO.	CY72	CY73	CY74	CY75	CY76	CY77
JAN	64.6	71.7	74.9	72.1	72.4	69.9
FEB	64.8	73.1	75.1	69.0	72.1	70.7
MAR	66.1	73.6	75.9	69.1	71.1	70.3
APR	67.0	72.8	74.5	68.0	69.1	71.0
MAY	67.1	73.5	76.5	71.7	69.5	71.7
JUN	67.5	73.9	77.5	73.1	67.1	72.1
JUL	67.4	74.7	76.5	73.5	66.8	72.5
AUG	66.3	75.0	77.4	73.9	67.4	72.4
SEP	67.5	75.0	77.0	73.1	67.1	73.3
OCT	68.7	75.3	75.1	70.9	69.0	69.9
NOV	70.6	76.4	75.2	71.0	69.2	70.1
DEC	71.5	76.3	73.4	71.9	69.2	72.7

MO.	CY78	CY79	CY80	CY81	CY82
JAN	73.6	85.8	90.9	84.2	71.3
FEB	72.8	87.2	91.1	82.2	73.1
MAR	76.4	87.4	90.7	81.6	71.5
APR	77.6	86.6	88.5	81.3	70.0
MAY	78.0	87.4	86.1	80.5	69.5
JUN	78.6	88.3	85.6	79.0	68.7
JUL	79.6	89.0	85.5	78.3	67.9
AUG	80.6	88.8	84.5	76.9	66.9
SEP	82.0	89.9	84.2	76.7	66.6
OCT	83.3	92.0	84.5	75.7	67.1
NOV	84.7	92.1	85.0	74.9	67.0
DEC	85.5	91.9	85.0	74.6	67.0

Appendix C
AEROSPACE CAPACITY UTILIZATION GRAPHS



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88.0
80.0
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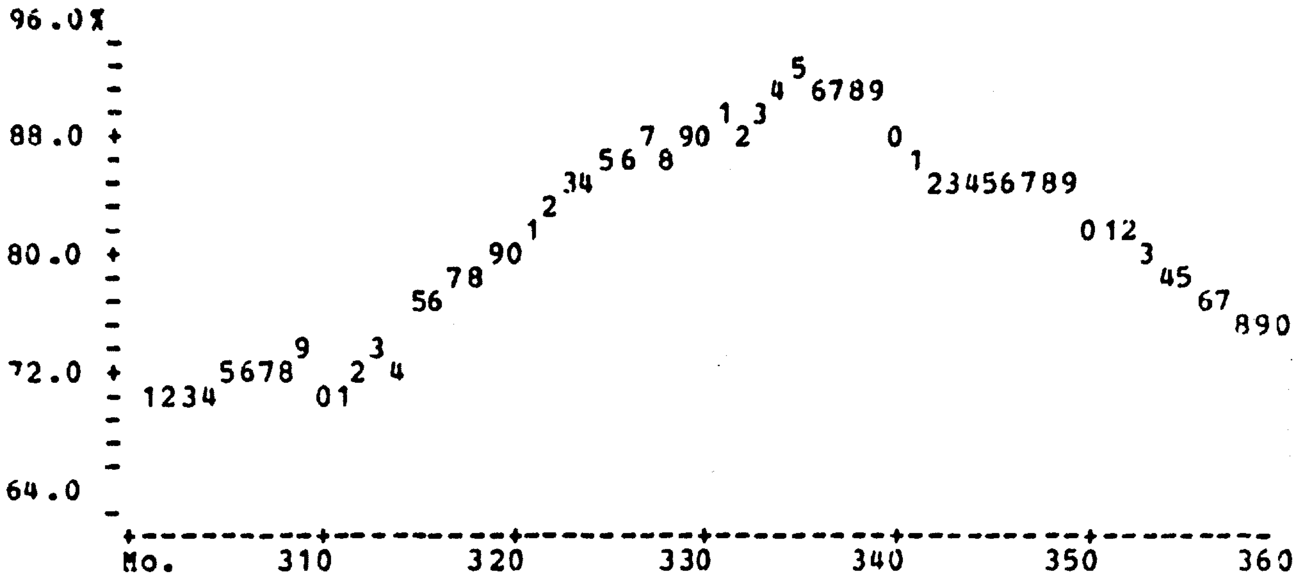
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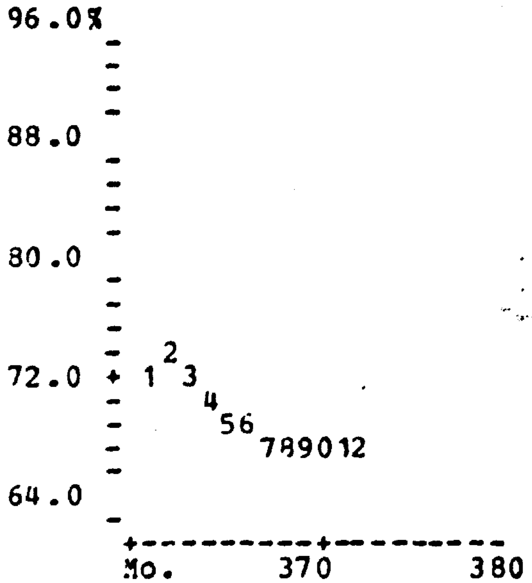
96.0%
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72.0
64.0
Mo.
370
380

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